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G R Bisby

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List of articles written

(continued from Volume I)

27. 1920. Short cycle Uromyces of North America. Bot. Gaz. 69: 193-217, plate X. Issued Mar. 16.

28. 1920. Give seed potatoes every chance. Potato Mag. 2[10]: 7, 28, fig.

29. 1920, Jackson, V.W, and GR Bisby. Potato top diseases in July and August. Man. Dept. Agr. Circ. 52, Third Ed., pp. 1-6. c. July 20.

30. 1920 Bisby, GR., and A.G. Tolaas. Potato diseases in Minnesota. Minn. Agric. Exp. Sta. Bull. 190: 1-44, figs. 1-28. out in July.

31. 1920. Bisby, GR., and AG Tolaas. The use of Bordeaux mixture for spraying potatoes. Minn. Agric. Exp. Sta. Bull. 192: 1-32, figs. 1-4.

32. 1920. Notes on potato diseases. Minn. Horticulturist 48: 170-171, 1 fig.

33. 1921. Sclerotinia diseases of sunflower in Manitoba. Abs. in Phytopath. 11: 49.

34. 1921. The coöperative potato spraying project. Abs. in Phytopath. 11: 60.

35. 1921. Potato diseases in winter. Man. Agric. Ext News 1⁴: 7. Feb.
36. 1921. The coöperative potato spraying project: progress report for 1918, 1919, and 1920. Phytopath. 11: 178-193.
37. 1921. Krantz, F.A., and G.R. Bisby. Relation of mosaic to running-out of potatoes in Minnesota. Minn. Agr. Exp. Sta. Bull. 197: 1-31, figs. 1-18. Sept.
38. Stem rot of sunflowers in Manitoba. Scient. Agric. 2: 58-61, 3 figs. Oct, 1921
39. The wheat rust problem. Managra 14⁵: 9-10. March, 1921
40. 1921. Bisby, G.R., and F.W. Brodrick. Potato growing in Northern Manitoba. Potato Mag. 4⁵: 14, 18, 19, 4 pls.
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SHORT CYCLE UROMYCES OF NORTH AMERICA

(WITH PLATE X)

G. R. BISBY

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VOLUME LXIX NUMBER 3

THE
BOTANICAL GAZETTE

MARCH 1920

SHORT CYCLE UROMYCES OF NORTH AMERICA[1]

G. R. BISBY

(WITH PLATE X)

The short cycle *Uromyces* may be segregated as a group by utilizing the criteria of life cycle and character of teliospores. Aside from any question of the validity of such bases for segregation, it is evident that it is a common practice thus to set apart this group, and that an opportunity is thereby afforded to consider relationships of such rusts to each other and to other rusts.

The short cycle *Uromyces* are of considerable interest, although as yet comparatively few species or even collections are recorded for North America. These rusts occur over a wide geographical range, however, and are parasitic upon widely separated families of hosts.

The writer has been privileged to examine the excellent collection of short cycle *Uromyces* in the herbarium of Dr. J. C. ARTHUR. This paper represents the results of the study of the group as made primarily for the *North American Flora*, but is presented separately in order to give notes and discussions not permissible in that publication.

[1] Abstract submitted before American Phytopathological Society at the New York meeting, and published in Phytopathology 7:74. 1917. Contribution from Botanical Department of Purdue University Agricultural Experiment Station.

Characters and relationships

The rusts considered in this paper are those which fulfil the following requirements:

Cycle of development includes only pycnia (sometimes) and telia, both subepidermal.

Pycnia deep-seated, globose or flask-shaped, with ostiolar filaments.

Telia erumpent, usually grouped; teliospores free, pediceled, 1-celled; wall firm, colored, smooth or variously sculptured; germination by a single promycelium from an apical pore.

Urediniospores normally absent but occasionally found in the telia.

The association of pycnia with telia has for some time been considered the criterion of short cycle rust (1, 4). The occurrence of definite aecia or uredinia (providing the evidence indicates that the aecia or uredinia belong with the telial stage present) suffices to exclude a specimen from the group under consideration. While some suspicion may be aroused by the presence of urediniospores, such spores occasionally occur in the telia. In the cases in which pycnia are only rarely or not at all produced, telia only being present, the arrangement and character of the telia usually may be utilized to indicate whether or not the specimen is short cycled; a grouping of the telia in definite circinating or crowded groups, or the occurrence of germination of the teliospores at or soon after maturity, usually means that such a specimen belongs with the group of rusts here treated. In certain cases, however, the telia are diffused, and other considerations must be brought to bear.

A study of the *Uromyces* forms of the rusts as represented in the Arthur herbarium and of the literature indicates that, in North America, only the 11 species described are at present known to belong in reality to short cycle forms.

Dietel (10) pointed out that the percentage of endemic species of rusts is higher in proportion to the isolation of the geographical region; that *Uromyces* shows a higher percentage of species in warmer than in colder regions; and that in both the Old and the New World the number of species of *Uromyces* is about one-third that of the number of species of *Puccinia*. It is to be noted that, so far as known, 8 of the 11 short cycle species of *Uromyces* are endemic to North America, and only 1 of the 11 species occurs also in Europe.

These forms are more especially found in the warmer parts of the continent, just as all *Uromyces* seem to be more numerous in warmer regions. While in North America some three times as many species of *Puccinia* as of *Uromyces* exist, the relation of the forms when divided according to their life cycle is strikingly different; for about 140 short cycle species of *Puccinia* are known for North America, in contrast to these 11 species of *Uromyces*.

P. and H. Sydow (**25**), in their monograph of *Uromyces*, described only the telial stage for 183 of the 504 species considered in that work. For only a very few of these, however, were pycnia described. When full information is in hand, a large number of the 183 forms will of course be found not to be short cycled. It appears, however, that a comparatively greater preponderance of these short cycle forms of *Uromyces* may be found in the more tropical regions. The observation of Magnus (**17**) and of Fischer (**15**), that increased altitude results in shortened life cycles for the rusts, is somewhat borne out by the fact that certain short cycle *Uromyces* are limited to the Rocky Mountain region. The effect of altitude and temperature can be better noted with the more numerous short cycle species of *Puccinia*.

Orton (**21**) has touched upon the relation of a group of rusts with a common life cycle, opsis forms of *Puccinia* (the genus *Allodus*), to other groups with different life cycles. Comparable relationships and correlations with other rusts are to be noted with the group of rusts considered in this paper; some attention is directed to these points with the discussion of the several species. The rust in its development is intimately dependent upon its host. Fischer (**13**) in 1898 emphasized the similarity between the teliospores of certain short cycle rusts and of long cycle heteroecious rusts whose aecia occurred upon the host of the short cycle form. He considered that this similarity indicated a phylogenetic relationship between such rusts with different life cycles. Dietel (**9**) considered that the Uredinales have probably developed during geological times along with their hosts. Arthur (**5**) has pointed out that the relationships of the rusts often reflect the relationships of the hosts upon which they occur. The writer (**6**) has also dealt somewhat with this point.

DIETEL (11) considered that *Uromyces* is the most primitive of the Pucciniaceae, both on account of the possession of 1-celled teliospores, and because it occurs upon such diverse families of monocotyledons and dicotyledons. Whether long cycle or short cycle rusts are more primitive is still a mooted question.

The existence of species of these rusts as lepto-forms or micro-forms, that is, whether or not the teliospores germinate upon maturity, while subject somewhat to seasonal variation, is a fairly constant and characteristic feature with each species.

Life history; cytology

The life cycle is simplified in a short cycle species to the extent that only telia, often with pycnia, are produced. The occasional occurrence of a few urediniospores in the telia is a phenomenon in common with other groups of rusts which ordinarily do not bear such spores.

FISCHER (12) first cultured a short cycle *Uromyces*. He sowed teliospores of *U. Cacaliae* (DC.) Unger upon *Adenostyles alpina* Kern, securing telia again without the intervention of any other spore stages. No trace of pycnia was found. In 1905 FISCHER (14) reported the culture of the short cycle species of *Uromyces* which occurs in Europe as well as in America, *U. Solidaginis*. He sowed teliospores upon *Solidago Virgaurea alpestris*, and in about 13 days noted the infection upon the leaves; telia were produced, but in no case were pycnia to be observed. While North American material of this species has not been cultured, it is supposed that similar conditions obtain here. SCHNEIDER (24) cultured *U. Scillarum* (Grev.) Wint., a short cycle form, and reported specialization as to hosts. The teliospores were found to be capable of germination, either at once or after a period of rest. No cultures of endemic North American short cycle *Uromyces* seem to have been reported. CARLETON (8), ARTHUR (3), and others, however, have reported cultures of some species of lepto-*Puccinia*. WILLE (27) recently found a sharp specialization of the lepto-form *Puccinia Arenariae* upon the different host genera attacked.

The evidence obtained from cultures indicates that similar conditions exist in the short cycle forms, both of *Uromyces* and *Puccinia*.

A greater specialization and fixity may exist with short cycle forms than with forms with long life cycles; of course fewer spore forms upon which variability may be manifested are present.

Pycnia may be produced, under certain conditions, in some of these short cycle species of *Uromyces* not yet known to produce pycnia. It is to be noted, however, that species in which the teliospores germinate at maturity, that is, lepto-forms, seldom produce pycnia. Teliospores cannot function directly as repeating spores, but in lepto-forms a comparatively rapid repetition is secured through the intervention of the basidiospores, which are produced immediately upon maturity of the teliospores.

Cytological work upon the short cycle rusts indicates that similar conditions obtain with the short cycle species, both of *Uromyces* and *Puccinia*. The work of SAPPIN-TROUFFY (23) upon the histology of the rusts included a study of the short cycle forms *Uromyces Ficariae* (Schum.) Lev. and *Puccinia malvacearum* Mont. His observations were corroborated and extended with the two rusts, among others, by BLACKMAN and FRASER (7). They found that the general vegetative mycelium of *Uromyces Ficariae* consists of uninucleate cells, some of the later vegetative, together with the sori-forming, mycelium being binucleate. They found similar conditions for *Puccinia malvacearum*, the binucleate condition evidently arising at several different points for each sorus, shortly before the sorus is formed. BLACKMAN and FRASER also observed that the short cycle forms *Puccinia Adoxae* Hedw.f. and *Uromyces Scillarum* (Grev.) Wint. had a binucleate rather than a uninucleate general vegetative mycelium, and suggested that it is "probable that in these two forms the conjugate condition is produced soon after infection by nuclear migration, or by cell fusion, between vegetative cells." OLIVE (20) discussed and figured sexual fusions near the base of the telium in a short cycle form, *Puccinia transformans* Ellis and Ev. Dealing with North American rusts, OLIVE (19) also reported that differing conditions as to the sporophytic and gametophytic generations occurred with certain short cycle *Puccinia* forms; while *Uromyces Rudbeckiae* Arth. and Holw. showed the anomalous extreme of possessing uninucleate cells through all the mycelium and sorus, even including the teliospores.

This phenomenon he was not able to explain fully. Other papers to be noted are those by WERTH and LUDWIGS (**26**), HOFFMAN (**16**), and MOREAU (**18**). A considerable summary of recent cytological work is presented by RAMSBOTTOM (**22**).

From this work it appears that the duration of the binucleate stage varies in different species of short cycle rusts, being brief, extended, or intermediate. Fusions between cells initiate this binucleate condition. Some life history problems, including the

TABLE I

HOST RELATIONSHIPS OF SHORT CYCLE *Uromyces*

Host	Species of Uromyces	Distribution	Mycelium	Common condition of germination	Pycnia
Liliaceae					
Erythronium	U. heterodermus	Rockies	Local or rather diffuse	Micro	Present
Cassiaceae					
Bauhinia	U. bauhiniicola	S.W. Mexico	Rather diffuse	Micro	Present
Bauhinia	U. jamaicensis	Mexico; West Indies	Local	Micro	Present
Fabaceae					
Psoralea	U. abbreviatus	Pacific Coast	Local, becoming rather diffuse	Micro	Present
Euphorbiaceae					
Chamaesyce, Tithymalus	U. Tranzschelii	Western N.A.	Diffuse	Micro	Present
Primulaceae					
Primula	U. nevadensis	Western N.A.	Local or rather diffuse	Micro	Not known
Myrsinaceae					
Myrsines	U. Myrsines	Costa Rica; S.A.	Local	Micro	Not known
Carduaceae					
Solidago	U. Solidaginis	W.N.A.; Europe	Local	Micro	Not known
Anaphalis	U. amoenus	Western N.A.	Local	Micro	Not known
Rudbeckia	U. Rudbeckiae	Central N.A.	Local	Lepto	Not known
Bidens	U. Bidentis	Porto Rico; S.A.	Local	Lepto	Not known

relative importance and relation of cell and nuclear fusions, some relations in the formation of pycnia in short cycle forms, the presence of perennial mycelium, etc., appear not to have been fully determined.

Hosts

The range of hosts attacked by these North American short cycle species of *Uromyces* embraces both the monocotyledons and dicotyledons. The situation is shown in table I.

Foreign species of short cycle *Uromyces* fill in several families not represented here. The wide range of hosts attacked indicates that these rusts do not form a restricted group; one might expect

to find affiliations with other forms of rusts upon the same or similar hosts through the various families, and such is the case. Under the species *U. heterodermus* a considerable comparison with rusts from related hosts is made, suggesting that certain groups of hosts appear to harbor rusts characterized by various definite morphological characters.

The geographical distribution of North American short cycle species of *Uromyces* would indicate further that the mountainous and more tropical regions furnish the most favorable location for these forms. Only *U. Rudbeckiae* has a comparatively wide range, a range including the plains area.

Whether or not it is more than a coincidence that the absence of pycnia and the occurrence of lepto-germination are found on hosts higher in the evolutionary scale, the writer is not prepared to say.

Taxonomic

With the progress of critical studies of North American rusts, other short cycle forms will undoubtedly be separated out, and further evidence secured as to the fixity and definiteness of the life cycle in certain of these rusts. *Uromyces heterodermus*, for example, was long placed with *U. Erythronii*, a correlated form. It was found also that *U. Bidentis* was a short cycle form which resembled *U. bidenticola* (P. Henn.) Arth. so far as characters of teliospores are concerned. It is no doubt true that other short cycle forms have been collected and placed with correlated long cycle forms, although cultures are needed to determine the life cycle in certain cases.

The 11 species of *Uromyces* considered have several points of similarity, one of which is the fact that all possess teliospores with apices more or less thickened. In none of the species were paraphyses, stromata, isolated peridial cells, or other accompanying structures found in the telia.

Key

Teliospores verrucose.
- Teliospores long, up to 43–47 μ
  - Wall up to 1.5 μ thick..... 1. *U. heterodermus*
  - Wall up to 2.5 μ thick..... 6. *U. nevadensis*
- Teliospores short, up to 30 μ..... 5. *U. Tranzschelii*

Teliospores reticulate.
- Spores 14–21 by 18–26 μ ..... 2. *U. bauhiniicola*
- Spores 12–17 by 16–23 μ ..... 3. *U. jamaicensis*

Teliospores smooth.
- Wall thin, 1–1.5 μ.
  - Spores narrow, 11–17 μ wide.
    - Spores 27–39 μ long ..... 7. *U. Myrsines*
    - Spores 19–32 μ long ..... 10. *U. Rudbeckiae*
  - Spores broad, 15–28 μ wide ..... 11. *U. Bidentis*
- Wall thick, 1.5–3 μ.
  - Apex thickened 6–12 μ ..... 8. *U. Solidaginis*
  - Apex thickened 3–7 μ.
    - Spores 27–40 μ long ..... 4. *U. abbreviatus*
    - Spores 19–30 μ long ..... 9. *U. amoenus*

1. UROMYCES HETERODERMUS Sydow, Ann. Myc. 4:29. 1906.

O. Pycnia amphigenous, not uncommon, gregarious in loose groups with the telia, 0.5–1.5 mm. across, inconspicuous, subepidermal, dark golden-brown, flattened globoid, 100–185 μ in diameter by 65–130 μ in height; ostiolar filaments few, loose, up to 65 μ long.

III. Telia amphigenous, numerous, scattered or in small groups, sometimes upon inconspicuous spots, roundish or oval, 0.3–2 mm. across, rather early naked, pulverulent, dark cinnamon-brown, surrounding epidermis noticeable; teliospores ellipsoid or broadly ellipsoid, 19–26×26–43 μ, rounded above, rounded or slightly narrowed below; wall dark golden-brown, 1.5 μ thick, thickened at the apex with a distinct hyaline papilla, 3–6 μ, coarsely verrucose above, with the markings often in longitudinal ridges, smoother below; pedicel hyaline, fragile, short.

ON LILIACEAE: *Erythronium grandiflorum* Pursh, Colorado, Montana, Utah, Washington, British Columbia; *E. montanum* S. Wats., Washington; *E. obtusatum* Goodding, Wyoming; *E. parviflorum* (Wats.) Goodding (*E. grandiflorum parviflorum* S. Wats.), Colorado, Montana, Oregon, Utah, Washington, Wyoming.

TYPE LOCALITY: Wasatch Mountains, Utah, on *Erythronium parviflorum*.

DISTRIBUTION: Rocky Mountain region from Colorado and Utah northward, and to the coast in Oregon.

EXSICCATI: Barth., Fungi Columb. *4694;* Barth., N.Am. Ured. *789, 1592, 1692;* Garrett, Fungi Utah. *118;* Ellis and Ev., Fungi Columb. *750*.

LITERATURE: SYDOW, Monog. Ured. 2:270. 1910; SACCARDO, Syll. Fung. 21:579. 1912.

This rust, previous to SYDOW's description in 1906, passed as *U. Erythronii* (DC.) Pass., a related European species possessing aecia. Thus ELLIS and EVERHART'S Fungi Columbiani *750* was issued as *U. Erythronii*. The host of this collection is undoubtedly *Erythronium parviflorum;* earlier collections of this host were frequently considered, as in this case, to be *E. grandiflorum*.

This rust occurs upon the species of *Erythronium* found in the western part of North America. According to ENGLER (ENGLER and PRANTL, Nat. Pflanz. 2^5:60. 1888) species of *Erythronium* occur particularly in North America. He places the following genera together to constitute the section Liloideae-Tulipeae: *Lilium*, *Fritillaria*, *Erythronium*, *Tulipa*, *Lloydia*, and *Calochortus*. Several rusts occur upon these genera of hosts. For the sake of comparison, all such rusts are tabulated. To avoid a personal factor, the data are largely from the SYDOWS' *Monograph*, and any supplementary data obtained are added in brackets. Parentheses indicate a rather free translation. Some data are taken from a paper by REES (Amer. Jour. Bot. **4**:368–373. 1917), who also presents drawings which support the contention that the rusts on these hosts possess rather unusual morphological similarities.

Table II shows many points of similarity in these rusts. It is to be noted that practically all possess amphigenous, rounded or minute, pulverulent sori, with spores broadly ellipsoid, rather similar as to size, with the wall usually moderately thick, apex somewhat thickened with a papilla, pedicel hyaline and short; and especially, all possess, in a striking manner, surface markings usually striate or verrucose and arranged in rows. This unanimity in morphological characters would indicate that a closely and definitely related group of rusts occurs upon these related hosts. Correlations, more or less perfect, obtain throughout this group of rusts upon the Liloideae-Tulipeae, and are found to extend further through the Liliaceae. Figs. 1–6 illustrate, for comparison, the teliospores of three of these rusts.

2. UROMYCES BAUHINIICOLA Arth. BOT. GAZ. **39**:389. 1905.—*Telospora Bauhiniicola* Arth., Result. Sci. Congr. Bot. Vienne 346. 1906.

TABLE II

Characters of rusts of Liloideae-Tulipeae

Rust	Host genus	Source of data	Life cycle	Geographical distribution	Leaf surface bearing telia	Shape of telia	Character of telia
Uromyces heterodermus Sydow	Erythronium	This paper	O, III	N.A.	Amphigenous	Round or oval	Pulverulent
Uromyces aecidiiformis (Strauss) Rees	(Fritillaria?)	Rees	O, I, III	Europe	Amphigenous	Elongated	Pulverulent
Uromyces Lilii (Link) Fuckel	Lilium	Sydow	O, I, III	(N.A.?), Europe	Amphigenous	Round or oblong	Pulverulent
Uromyces Erythronii (DC.) Pass.	Erythronium	Sydow	O, I, III	Europe	Amphigenous	Roundish	Pulverulent
Uromyces mogianensis Bubak	Fritillaria	Sydow	O, I*, III	Asia, Europe, Africa	Amphigenous	Round or oblong	Pulverulent
Uromyces Miurae Sydow	Fritillaria	Rees	(O, I)? III	Japan, N.A.	Amphigenous	Round or ellipsoid	Pulverulent
Uromyces Fritillaria (Schlechtd.) Thüm	Fritillaria	Rees	O, I, III	Europe	Amphigenous	Elliptical	Pulverulent
Uromyces Tulipae Dietel	Tulipa	Sydow	I, III	Japan	Amphigenous	Minute	Pulverulent
Uromyces japonicus Sydow	Lilium	Sydow	II, III	Japan	(Amphigenous)	Round	Pulverulent
Uromyces Holwayi Lagerh	Lilium	Sydow	[O, I], II, III	N.A.	Amphigenous	Minute round	Pulverulent
Nigredo Lilii (Clint.) Arth	Lilium	Flora	O, I, II, III	N.A.	Amphigenous	.....	Pulvinate?
Puccinia Calochorti Peck	Calochortus	Sydow	(O), I, III	N.A.	Chiefly hypophyllous	Round	Pulverulent
Puccinia Prostii Mong	Tulipa	Sydow	III	Europe	Amphigenous	Oblong	[Pulverulent]
Puccinia Tulipae Schroet	Tulipa	Sydow	III	Europe	Chiefly hypophyllous	Minute	.....

Rust	General shape of teliospores	Size of teliospores	Wall in μ	Apex in μ	Apex character	Sculpturing	Pedicel
Uromyces heterodermus Sydow	Broad, ellipsoid	19–26×26–43	1–5	3–6	Hyaline papilla	Coarsely verrucose in rows	Hyaline, short
Uromyces aecidiiformis (Strauss) Rees	Broad, ellipsoid	23–27×31–35	About 3	[to 5]	Hyaline apiculus	Rugose in rows	Hyaline, short
Uromyces Lilii (Link) Fuckel	Broad, ellipsoid	22–30×28–44	2–3.5	[to 5]	Hyaline papilla	Rugose or verrucose in rows	Hyaline, short
Uromyces Erythronii (DC.) Pass.	(Broad, ellipsoid)	16–25×22–42	1.5–2	[to 6]	Hyaline papilla	Anastomose in rows	Hyaline, short
Uromyces mogianensis Bubak	Subglobose	26–32×26–38	3–6	.....	Hyaline papilla	Verrucose in rows	Hyaline, deciduous
Uromyces Miurae Sydow	Ellipsoid	14–23×24–35	1.5–2	to 5	Hyaline apiculus	Verrucose in rows	Hyaline, short
Uromyces Fritillaria (Schlechtd.) Thüm	Broad, ellipsoid	23–31×31–42	.....	to 5	Hyaline apiculus	Rugose in rows	Hyaline, short
Uromyces Tulipae Dietel	Broad, ellipsoid	20–28×26–40	.....	.....	Hyaline papilla	Reticulate-striolate	Hyaline, short
Uromyces japonicus Sydow	Ovate	20–28×28–46	1.5	.....	Hyaline papilla	Verrucose in rows	Hyaline, deciduous
Uromyces Holwayi Lagerh	Broad, ellipsoid	20–28×24–42	[2–2.5]	[5–7]	Hyaline papilla	Verrucose in rows	Hyaline, deciduous
Nigredo Lilii (Clint.) Arth	Broad, ellipsoid	18–25×29–39	2–2.5	5–7	Apiculus	Rugose in ridges	Hyaline, short
Puccinia Calochorti Peck	(Broad), ellipsoid	22–30×33–40	[1.5–2.5]	[3–5]	.....	Verrucose	Hyaline (short)
Puccinia Prostii Mong	(Broad), ellipsoid	34–40×54–66	[2–3]	[3]	(Aculeate)	Aculeate, strongly	[Hyaline] (short)
Puccinia Tulipae Schroet	Broad, ellipsoid	21–32×30–44	.....	.....	.....	Verrucose	Hyaline, short

* Bubak says O with III.

O. Pycnia epiphyllous, few, gregarious in small groups, usually opposite the telia, punctiform, subepidermal, brownish, flattened globose, 60–130 μ in diameter by 30–65 μ in height; ostiolar filaments compact, short.

III. Telia at first hypophyllous, becoming also somewhat epiphyllous, numerous, scattered or in small groups, roundish, small, 0.2–1 mm. across, early naked, pulverulent, chocolate-brown, surrounding epidermis inconspicuous; teliospores globoid or broadly ellipsoid, 14–21 by 18–26 μ, rounded at the ends; wall cinnamon or chestnut brown, thick, 2.5–4 μ, apex thicker, 4–7 μ, with a paler, broad umbo, finely reticulated; pedicel pale or colorless, often roughened below, rather fragile but sometimes two or three times as long as the spore.

On Cassiaceae: *Bauhinia Pringlei* S. Wats., Jalisco; *Bauhinia* sp., Guerrero.

Type locality: Guadalajara, Mexico, on *Bauhinia Pringlei.*

Distribution: Known only from Southwest Central Mexico.

Illustration: Ark. Bot. Stockh. 4: *pl. 1. fig. 9.*

Exsiccati: Barth., N.Am. Ured. *286.*

Literature: Vestergren, Ark. Bot. Stockh. 4:28–29. 1905; Sydow, Monog. Ured. 2:80, 81. 1909; Saccardo, Syll. Fung. 21:550–551. 1912.

3. Uromyces jamaicensis Vesterg. Ark. Bot. Stockh. 4:33. 1905.

O. Pycnia chiefly epiphyllous, gregarious in small groups with the telia, subepidermal, brownish, flattened, 60–100 μ in diameter by 45–70 μ in height; ostiolar filaments compact, hardly extending beyond the ostioles.

III. Telia amphigenous, numerous, gregarious in small groups or occurring singly, sometimes on small yellowish spots, roundish, small, 0.1–1 mm. across, early naked, pulverulent, chestnut-brown, surrounding epidermis noticeable; teliospores globoid, broadly ellipsoid or obovoid, 12–17 × 16–23 μ, rounded or slightly narrowed at the ends; wall cinnamon-brown, 1.5–2 μ (sometimes up to 3.5 μ) thick, thicker at the apex, up to 5 μ, with a lighter crater or cap-shaped crown, closely and finely reticulate, appearing verrucose under the lower powers of the microscope; pedicel pale, fragile, 4–15 μ long.

On Cassiaceae: *Bauhinia divaricata* L., Cuba, Guanajuoto; *B. Pauletia* Pers., Porto Rico; *B. porrecta* Sw., Jamaica.

Type locality: Constant Spring, Jamaica, on *Bauhinia* sp.

Distribution: Mexico and the West Indies.

Illustration: Ark. Bot. Stockh. **4**: *pl. 2. fig. 14.*

Literature: Sydow, Monog. Ured. **2**:84. 1909; Saccardo, Syll. Fung. **21**:552–553. 1912.

This species may perhaps be distinguished from the preceding by the somewhat reduced length and breadth of the teliospores, the wall thickness often being less also. The differences described by Vestergren (*loc. cit.*) have not been found to hold entirely throughout the collections at the Arthur herbarium. Some differences, however, are still to be found between the two species of rust, and they are maintained as separate species, at least pending further collections.

Vestergren's supposition that *Uromyces jamaicensis* is a micro-*Uromyces* has been corroborated by the discovery of pycnia associated with telia upon a Cuban specimen of *Bauhinia divaricata*. The specimen upon *B. porrecta* collected by Thaxter has not been seen, but Vestergren's type collection has been examined.

Vestergren separated 17 species of *Uromyces* upon the host *Bauhinia*, for none of which aecia are known. Evident similarities are shown between the species as he described and figured them. *Uromyces* only are known to occur upon *Bauhinia*. Many species of *Bauhinia* occur in the tropics; related genera, as shown by Engler and Prantl's classification, are chiefly genera upon which rusts have not yet been found. The reticulate nature of the sculpturing upon the surface of the teliospores of these two species is minute, but evident under higher microscopic power. Figs. 7–10 illustrate the two species.

4. Uromyces abbreviatus Arth. Bull. Torr. Bot. Club **42**:587. 1915.

O. Pycnia hypophyllous, scattered among the telia, inconspicuous, subepidermal, deep seated, dark honey-yellow, globose or flattened globose, 115–200 μ in diameter by 95–140 μ in height; ostiolar filaments dense, often falling away, up to 60 μ in length.

III. Telia hypophyllous, rarely also epiphyllous, densely clustered, becoming scattered over considerable areas, roundish,

0.2–0.7 mm. across, early naked, pulverulent, chocolate-brown, surrounding epidermis at first evident, later often hidden by the loose spores; teliospores ellipsoid or irregularly obovoid, 21–26 × 27–40 μ (sometimes variable in size, and larger), rounded above, rounded or narrowed below; wall chestnut-brown, 1.5–3 μ thick, apex 3–5 μ thick, often with a slight umbo over the pore, smooth; pedicel colorless, delicate, fugacious, half as long as the spore or less.

On Fabaceae: *Psoralea physodes* Dougl., California, Washington, British Columbia; *P. Purshii* Vail, Nevada.

Type locality: Winnemucca, Nevada, on *Psoralea Purshii*.

Distribution: Pacific Coast region, west of the mountains, from British Columbia to California.

Exsiccati: Barth., N.Am. Ured. *1582;* D. Griff., W.Am. Fungi *390;* Barth., Fungi Columb. *4884*.

The type of this species is Griffith's West American Fungi *390*, which was issued as *Uromyces Psoraleae* Peck. *U. Psoraleae* possesses aecia, however. *U. abbreviatus*, while without aecia, and possessing pycnia with the telia, resembles *U. Psoraleae* in the telial stage, as indicated by Arthur in the notes with the original description. While *U. Psoraleae* extends to the Pacific Coast, it is more common in the Rocky Mountain region, and extends over the plains to the east of the mountains. *U. abbreviatus*, so far as known, is limited to the region west of the Rockies.

There is an unconnected *Aecidium* (*Aecidium onobrychidis* Burrill, Bull. Ill. State Lab. Nat. Hist. **2**:225. 1885) upon *Psoralea Onobrychis*, represented as far as known by the one collection by Seymour in Illinois, and distributed by Ellis and Everhart as North American Fungi *1826*. No other species of rust are reported for the genus *Psoralea*, and these species are only known in North America. Related hosts, as given by Engler and Prantl, except for the genus *Indigofera* in an adjoining section, are scarcely known to be attacked by rusts; no closely related rusts are evident upon related hosts.

While the type collection is from an altitude of about 5000 ft., other collections in the Arthur herbarium are from nearer the coast, at much less altitude, extending almost down to sea-level.

5. Uromyces Tranzschelii Sydow; Tranzschel, Ann. Myc. 8:20. 1910.

O. Pycnia hypophyllous, scattered among the telia, or in groups, noticeable, subepidermal, dark yellow, globoid or flask-shaped, 100–145 μ in diameter by 75–130 μ in height; ostiolar filaments dense, agglutinated into a truncate column, 50–80 μ in height, 50–70 μ in diameter at the ostiole.

III. Telia hypophyllous, occasionally sparingly epiphyllous, numerous, evenly scattered over large areas, or sometimes in groups around the pycnia, roundish, 0.2–0.6 mm. across, early naked by a central pore, pulverulent, chestnut-brown, surrounding epidermis crateriform, conspicuous; teliospores globoid or ellipsoid, 15–22 × 19–30 μ, rounded at the ends, wall cinnamon-brown, 1.5–2.5 μ thick, apex 3–5 μ thick with a low, sub-hyaline apiculus, minutely verrucose, the markings often in irregular longitudinal lines; pedicel colorless, deciduous.

On Euphorbiaceae: *Chamaesyce serpens* (H.B.K.) Small (*Euphorbia serpens* H.B.K.), California; *Tithymalus montanus* (Engelm.) Small (*Euphorbia montana* Engelm.), Colorado, New Mexico, Utah, Wyoming; *T. robustus* (Engelm.) Small (*Euphorbia montana robusta* Engelm.), Colorado, Utah, Wyoming; *Tithymalus* sp. (*Euphorbia Palmeri* Engelm.), Lower California.

Type locality: Colorado, on *Euphorbia montana*.

Distribution: From Wyoming to New Mexico, California, and Lower California.

Exsiccati: Barth., N.Am. Ured. *499;* Ellis and Ev., Fungi Columb. *1069;* Ellis and Ev., N.Am. Fungi *2230;* Garrett, Fungi Utah. *97*.

Literature: Tranzschel, Ann. Myc. 8:1–35. 1910; Sydow, Monog. Ured. 2:171–172. 1910; Saccardo, Syll. Fung. 21:560–561. 1912; Dietel, Hedw. 28:185–187. 1889; Arthur, Bull. Torr. Bot. Club 45:152. 1918.

This rust passed as *Uromyces scutellatus* (Schrank.) Lev., a European species, until Sydow's description in 1910. Tranzschel pointed out that *U. Tranzschelii* is similar to *U. monspessulanus* Tranz.; indeed, other similarities to various Euphorbiaceous rusts are evident. In his study of the autoecious rusts upon *Euphorbia*, Tranzschel stated that most European autoecious species with telia from diffused mycelium had passed as two species, *Uromyces scutellatus* or *U. excavatus;* he divided such forms into some 12 species, and found a total of 27 autoecious species of *Uromyces*

upon hosts belonging to the various sections of the genus *Euphorbia*. That these species are related is evidenced by the fact that many had passed under one name; furthermore, many similarities are to be noted from TRANZSCHEL'S descriptions. For example, all but one species are listed as having verrucose or striolate teliospore walls. A table showing characters in a manner similar to those tabulated under *U. heterodermus* would be illuminating as indicating relationships between *U. Tranzschelii* and other species of rust upon related hosts. The writer considered it sufficient, however, to call attention to TRANZSCHEL'S work as indicating relationships. Certain heteroecious species with aecia upon *Euphorbia* likewise show resemblances to *U. Tranzschelii*.

Both ELLIS and EVERHART'S Fungi Columbiani *1069* and North American Fungi *2230* were issued as *U. scutellatus*, while GARRETT'S Fungi Utahensis *97* was issued as *U. andinus* P. Magn., a related South American rust.

The range of *U. Tranzschelii* begins at about the western limit of the range of the related species *U. proeminens* (DC.) Pass., and continues westward to the Pacific Coast. Range conditions comparable with those of *U. abbreviatus* are thus shown, and neither of these short cycle forms necessarily occurs at high altitudes.

TRANZSCHEL (*loc. cit.*, p. 20) considered the rust upon *Euphorbia Palmeri* to be different, apparently another species. The specimen studied by the writer is not considered different from other specimens of *U. Tranzschelii*.

DIETEL (*loc. cit.*) commented upon ELLIS and EVERHART'S North American Fungi *2230*, especially concerning the relationship of an *Aecidium* upon the same host distributed as no. *2215* of the same exsiccati. It is true that *Aecidium Tithymali* Arth. occurs upon the same hosts, sometimes upon the same leaves, as *Uromyces Tranzschelii*. The situation in regard to this *Aecidium Tithymali* is uncertain. Germination tests show that it is a true *Aecidium* and not an *Endophyllum*. Its alternate host, however, has not been found. ARTHUR (*loc. cit.*) has discussed this *Aecidium* and its possible relation to *U. Tranzschelii*.

6. UROMYCES NEVADENSIS Hark. Bull. Calif. Acad. Sci. 1:36. 1884.—*Caeomurus nevadensis* Kuntze, Rev. Gen. 3³:450. 1898.

O. Pycnia unknown.

III. Telia amphigenous, circinating in groups 2–5 mm. across, or somewhat scattered, round or oval, 0.2–1.0 mm. across, early naked, pulvinate, becoming somewhat pulverulent, chestnut-brown, ruptured epidermis conspicuous; teliospores oblong, oblong-obovoid, or ellipsoid, 19–27 × 29–47 μ, rounded at the apex, rounded or narrowed toward the base; wall cinnamon-brown, lighter or colorless at the apex, moderately thick, 1.5–2.5 μ, thickened at the apex, 5–7 μ, moderately and rather finely verrucose; pedicel colorless, fragile.

On Primulaceae: *Primula suffrutescens* Gray, Nevada.
Type locality: Lake Tahoe, Nevada, on *P. suffrutescens*.
Distribution: Known only from the type locality.
Literature: Magnus, Ber. Deutsch. Bot. Gesells. **18**:451–459. 1900.
Illustration: Magnus, *loc. cit. pl. 16. figs. 16–19.*

The writer is considerably indebted to the members of the botanical staff at the Purdue Station for the preceding. Arthur in a letter states that "a careful study of this species seems to leave little doubt that it is a distinctly American species and a short cycle one. This was the conclusion reached by Magnus in 1900." The one collection known was made by Harkness, and a specimen has been studied by the writer.

7. Uromyces Myrsines Diet. Hedwigia **36**:26. 1897.

O. Pycnia unknown.

III. Telia hypophyllous, crowded upon reddish or brownish spots 2–10 mm. in diameter, margin of spots usually elevated, roundish, 0.1–0.2 mm. in diameter, often confluent, early naked, pulvinate, light chocolate-brown, ruptured epidermis inconspicuous; teliospores oblong or oblong-ellipsoid, 13–16 × 27–39 μ, rounded or acute above, narrow below; wall pale golden-brown, rather thin, 1–1.5 μ, thickened at the apex, 3–8 μ, smooth; pedicel colorless, short.

On Myrsinaceae: *Ardisia compressa* H.B.K., Costa Rica.
Type locality: Rio de Janeiro, Brazil, on *Myrsine* sp.
Distribution: Costa Rica; also in South America.
Literature: Arthur, Mycologia **10**:124, 1918; Sydow, Monog. Ured. **2**:46. 1909.

This rust was known only from South America before its discovery by HOLWAY in one locality in Costa Rica. South American specimens have been distributed by E. ULE, Herbarium Brasiliense no. *2136*. ARTHUR suggests that *U. marginatus* Bomm. and Rouss may be a synonym. SYDOW gives *U. Rhapaneae* Henn. and *U. Usterianus* Diet. as synonyms. While SYDOW was probably right, it has been impossible to examine specimens of these two collections.

8. UROMYCES SOLIDAGINIS (Sommerf.) Niessl, Verh. Natur. Ver. Brunn **10**:163. 1872.—*Caeoma Solidaginis* Sommerf. Suppl. Fl. Lapp. 234. 1826; *Caeomurus Solidaginia* Kuntze, Rev. Gen. **3**[3]:450. 1898; *Telospora Solidaginia* Arth., Result. Sci. Congr. Bot. Vienne 346. 1906.

O. Pycnia not found; probably wanting.

III. Telia hypophyllous, sometimes also petiolicolous or caulicolous, crowded and often confluent in orbicular groups upon the leaves, or in elongated groups upon the petioles or stems, 2–10 mm. across, upon yellowish spots, roundish, small, 0.3–0.7 mm. across, early naked, compact, pulvinate, chocolate-brown, surrounding epidermis noticeable; teliospores obovate or ellipsoid, 17–25 × 24–33 μ, narrowed or rounded at the ends; wall chestnut-brown, 1.5–3 μ thick, much thicker at the apex, 6–12 μ, smooth; pedicel nearly colorless, about as long as the spore.

ON CARDUACEAE: *Solidago polyphylla* Rydb., Colorado; *S. serotina* Ait., Montana, Washington, Wyoming.

TYPE LOCALITY: Nordland, Sweden, on *Solidago virgaurea*.

DISTRIBUTION: Colorado to Montana and Washington, also in Europe and Asia.

ILLUSTRATIONS: Archiv. Naturw. Land. Bohmen **13**: *fig. 12;* Beitr. Krypt. Schweiz **2**[2]: *fig. 44*.

EXSICCATI: D. Griff., W.Am. Fungi *361*; Ellis and Ev., N.Am. Fungi *2883*.

LITERATURE: COOKE, Grev. **5**:152. 1877; WINTER, in Rab. Krypt. Fl. **1**[1]:141. 1881; SACCARDO, Syll. Fung. **7**:566. 1888; FISCHER, Beitr. Krypt. Schweiz **2**[2]:59, 543. 1904; FISCHER, Ber. Schw. Bot. Gesells. **15**:(1–2). 1905; HARIOT, Les Ured. 216. 1908; SYDOW, Monog. Ured. **2**:10. 1909.

This is the one species of *Uromyces* included in this paper which is not endemic to the Americas. FISCHER (1905) reported cultures of this rust. He also (1898) pointed out the correlation between this species and *U. Junci* (Desmaz.) Tulasne, which bears aecia

upon hosts related to *Solidago*. The range of both *U. Solidaginis* and *U. Junci* in North America is similar, both occurring in the western part.

Uromyces Junci-effusi Sydow resembles *U. Solidaginis* in the telial stage; the aecial connection is not known for this form. Curiously not *Puccinia Solidaginis* Peck, but *P. Asteris* Duby (both are short-cycled) shows a correlation with *Uromyces Solidaginis*. Of the short cycle species of *Puccinia* upon *Solidago* in America, one, *P. Virgauriae* (DC.) Lib., is more eastern, possesses stromata, and has thin-walled teliospores. *P. Solidaginis*, although a western form, has very large teliospores. *P. Asteris*, however, is very similar to *Uromyces Solidaginis* in gross and microscopic characters, except in the possession of 2-celled teliospores. *Puccinia Asteris* is a more common rust, and while rare west of the Rockies, is found over most of North America. Figs. 19–22 illustrate *U. Solidaginis* from America and Europe and *P. Asteris*.

COOKE (*loc. cit.*) reported *Uromyces Solidaginis* from Maine. Collections from Eastern North America are not at hand; further doubt may be attached to COOKE's reported collection from the fact that he states that the spores are reticulated. GRIFFITH's West American Fungi *361*, although issued as *Puccinia Solidaginis*, is in reality *Uromyces Solidaginis*.

9. UROMYCES AMOENUS Sydow, Ann. Myc. **4**:28. 1906.

O. Pycnia unknown.

III. Telia hypophyllous, densely grouped and often confluent on circular purplish spots, 2–8 mm. across, the margin of the spots yellow, roundish, small, 0.2–0.7 mm. across, early naked, compact pulvinate, dark chestnut-brown, covered by the tomentose pubescence of the host, ruptured epidermis inconspicuous; teliospores globoid, obovoid, or ellipsoid, 16–23 × 20–30 μ, usually rounded above and narrowed below; wall dark golden-brown or cinnamon-brown, moderately thick, 1.5–2.5 μ, apex thicker, 4–7 μ, smooth; pedicel pale yellowish, up to the length of the spore.

ON CARDUACEAE: *Anaphalis margaritacea occidentalis* Greene, Oregon; *A. subalpina* (A. Gray) Rydb. (*A. margaritacea subalpina* A. Gray), Idaho, Oregon, Washington, Wyoming, British Columbia.

TYPE LOCALITY: Washington, on "*Gnaphalium* (*Anaphalis*) *margaritacea*."

DISTRIBUTION: Wyoming to British Columbia and Oregon.

EXSICCATI: Ellis and Ev., Fungi Columbiani *1795;* Barth., N.Am. Ured. *1385, 1584.*

LITERATURE: SYDOW, Monog. Ured. 2:4. 1909; SACCARDO, Syll. Fung. 21:570. 1912.

Several collections of this rust are in the Arthur herbarium. Although the hosts of some collections are labeled *Anaphalis margaritacea*, it would appear that the name *A. subalpina* should be used for almost all collections in hand (compare COULTER and NELSON, New Manual of the Botany of the Central Rocky Mountains, p. 537).

ELLIS and EVERHART'S Fungi Columbiani *1795* was issued as *Uromyces Gnaphalii* Ellis and Ev., but is *U. amoenus*. *U. Gnaphalii* has been found to be a synonym of *U. intricatus* Cooke.

10. UROMYCES RUDBECKIAE Arth. and Holw. Bull. Iowa Agric. Coll. 1884. 154. 1885.—*Caeomurus Rudbeckiae* Kuntze, Rev. Gen. 3^3:450. 1898; *Telospora Rudbeckiae* Arth., Result. Sci. Congr. Bot. Vienne 346. 1906.

O. Pycnia unknown.

III. Telia hypophyllous, occasionally also epiphyllous, densely gregarious upon brownish spots, paler below, 1–10 mm. across, rather circinate, small, 0.2–0.8 mm. in diameter, early naked, compact, pulvinate, cinnamon-brown, soon cinereous from germination, surrounding epidermis not noticeable; teliospores ellipsoid, obovoid, or pyriform, 11–17×19–32 μ, rounded, acute, or obtuse at the apex, narrowed below; wall yellowish or very pale chestnut-brown, thin, 1 μ, apex thicker, 5–8 μ, smooth; pedicel hyaline, twice as long as the spore or less.

ON CARDUACEAE: *Rudbeckia laciniata* L. (*R. ampla* A. Nels.), Colorado, Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Montana, Nebraska, New Mexico, North Dakota, Pennsylvania, Wisconsin, Wyoming, Ontario; *Rudbeckia* sp., Texas.

TYPE LOCALITY: Decorah, Iowa, on *Rudbeckia laciniata.*

DISTRIBUTION: Ontario and Pennsylvania to Montana and Texas.

ILLUSTRATION: Arth. and Holw. Ured. Exs. Ic. 1: *pl. 1. fig. 1.*

EXSICCATI: Arth. and Holway, Ured. Exs. Ic. 1: Barth., Fungi Columb. *4394;* Barth., N.Am. Ured. *299, 1099, 1397;* Brenckle, Fungi Dak. *274;* Ellis and Ev., Fungi Columb. *2097;* Ellis, N.Am. Fungi *1439;* Rab.-Wint., Fungi Eur. *3412;* Sydow, Ured. *1305, 1962.*

LITERATURE: BURRILL, Bull. Ill. State Lab. Nat. Hist. 2:163. 1885; SACCARDO, Syll. Fung. 7:581. 1888; ARTHUR and HOLWAY, Bull. Lab. Nat. Hist. State Univ. Iowa 3:44. 1895; SYDOW, Monog. Ured. 2:7–8. 1909.

Uromyces Rudbeckiae has been collected more frequently than any North American species of the group. Its range embodies the greater part of the plains area, and extends to the Rocky Mountains.

DIETEL (Ann. Myc. 8:305. 1910) considered *Uromyces Komerovii* Bubak on *Solidago Virgaurea* identical with *U. Rudbeckiae*. No specimens of the former have been seen, although a collection on *Solidago Virgaurea* in the herbarium has not been found to differ from *U. Solidaginis*.

The only other rust found upon *Rudbeckia* is *Aecidium Compositarum* Auct., recently found to belong with *U. perigynius* Halsted (Mycol. 9:307), a connection suspected from the fact that the telial stage of *U. Rudbeckiae* is similar to the telial stage of *U. perigynius*. A type of correlation which has frequently been of service in indicating alternate stages of heteroecious rusts is thus evidenced. The cytological work upon this species is noted earlier in this paper.

11. UROMYCES BIDENTIS Lagerh. Bull. Soc. Myc. Fr. 11:213, 1895.—*Caeomurus Bidentis* Kuntze, Rev. Gen. 3^3:449. 1898; *Uromyces densus* Arth. Mycologia 7:196. 1915.

O. Pycnia unknown.

III. Telia hypophyllous, numerous, in small circinating groups on roundish, discolored spots, 1–4 mm. across, sometimes confluent, roundish or oval, 0.1–1 mm. across, the central sorus larger, surrounded by smaller ones, early naked, compact, pulvinate, dull cinnamon-brown, becoming waxy-cinereous from germination, surrounding epidermis inconspicuous; teliospores obovoid or oblong, 15–28×30–45 μ, rounded or narrowed above, narrowed below; wall pale golden or cinnamon-brown, thin, 1 μ, thicker above, 4–9 μ, smooth; pedicel hyaline, once or twice the length of the spore or less.

ON CARDUACEAE: *Bidens leucantha* (L) Willd., Porto Rico; *B. pilosa* L., Porto Rico; *Bidens* sp., Costa Rica.

TYPE LOCALITY: Ecuador, South America, on *Bidens andicola*.

DISTRIBUTION: Porto Rico and Central America; also in South America.

The Sydows (Monog. Ured. 1:3. 1909) misapplied Lagerheim's name to the species with uredinia, now called *Uromyces bidenticola* (P. Henn.) Arth. The situation in regard to these two rusts is discussed by Arthur (Mycologia 9:71. 1917), and he also (Mycologia 10:127. 1918) suggests that it is possible that a fixity of life cycle may not occur in these *Bidens* rusts. *U. Bidentis* is correlated with *U. Bidenticola*, differing only in the life cycle and in the characters of the telia, which are coalescent and thickened into cushions in *U. Bidentis*. Specimens are at hand also from South America; Lagerheim's collection from the type locality has been examined.

Puccinia Bidentis Diet. and Holw., Bot. Gaz. 24:32. 1897, collected by Holway in Mexico, apparently is not a correlated species.

Excluded species

Uromyces hyalinus Peck, Bot. Gaz. 3:34. 1878.—*U. Sophorae* Peck, Bull. Torr. Bot. Club 12:35. 1885; *Caeomurus hyalinus* Kuntze, Rev. Gen. 3³:450. 1898; *Telospora hyalina* Arth., Result. Sci. Congr. Bot. Vienne 346. 1906.

Literature: Saccardo, Syll. Fung. 7:581. 582. 1888; Hariot, Revue Mycol. 14:21. 1892; Sydow, Monog. Ured. 2:128. 1909.

This rust, first described upon *Sophora sericea* from Colorado, and made the type of the genus *Telospora*, has been found to possess uredinia. Olive, in his paper on intermingling of perennial sporophytic and gametophytic generations, etc. (Ann. Myc. 11:309. 1913), mentions that Arthur has called attention "to the fact that *Uromyces Sophorae* seems to possess a similar habit [that is, an intermingling of mycelia] to the perennial rusts under discussion." In any event, the presence of uredinia, in some cases at least, suffices to exclude this species from the short cycle forms.

Uromyces Pavoniae Arth., Bull. Torr. Bot. Club 31:1. 1914.—*Telospora Pavoniae* Arth., Result. Sci. Congr. Bot. Vienne 346. 1906.

Literature: Saccardo, Syll. Fung. 17:250. 1905; Sydow, Monog. Ured. 1:59. 1909.

This rust, described upon *Malache scabra* B. Vogel (*Pavonia racemosa* L.) from Porto Rico and Jamaica, belongs with *Puccinia*

heterospora Berk. and Curt. An examination of the material shows that a very few 2-celled teliospores are present. *P. heterospora*, upon related Malvaceous plants, is characterized by the preponderance of 1-celled mesospores such as those upon *Pavonia*.

ARTHUR (Mycologia **9**:80. 1917) has given a brief discussion of the situation here. *Uromyces pictus* Thuem. upon *Abutilon* was also found to possess a few 2-celled teliospores and was placed with *Puccinia heterospora* by SYDOW (Monog. Ured. **2**:58 and 356. 1910).

UROMYCES MONTANA Arth., BOT. GAZ. **39**:386. 1905.—*Telospora montana* Arth., Result. Sci. Congr. Bot. Vienne 346. 1906.

The type collection of this species possessed also aecia, which were at the time considered to belong with *Uromyces Lupini* B. and C. Subsequent collections in Guatemala by KELLERMAN and HOLWAY, however, show the same association of aecia and telia; furthermore, these aeciospores are larger and thicker walled than the aeciospores of *U. Lupini*. The grouped arrangement of the telia and the thin walls of the teliospores and their germination at maturity indicate a short cycle form, but nevertheless it is considered probable that the aecia go with the telia. *U. elatus* Syd., also upon *Lupinus*, shows the same situation as regards association of aecia with telia resembling those of a short cycle form. I am indebted to Dr. MAINS of Purdue for work upon this species.

UROMYCES CUPANIAE Arth., Mem. Torr. Bot. Club **17**:131. 1918.—*Uredo cristata* Speg., Anal. Soc. Ci. Argent **17**:119. 1884.

This rust, although short-cycled, is excluded from this group, since, as noted by ARTHUR, it has marked affinities with other groups of rusts rather than with the group herein treated.

Conclusions

Eleven species of *Uromyces* possessing only telia and pycnia, or telia alone, are now considered to be present in North America. These are found especially in the higher and warmer portions of the continent, and occur upon 7 widely separated host families. While these rusts form a group agreeing as to life cycle and as to the 1-celled character of the teliospores, it is not considered that phylogenetic interrelationship is thereby shown, morphological evidence indicating rather that the relationship of a

species of these rusts is found in other rusts (of various life cycles and with 1 or 2-celled teliospores) upon the same or related hosts. Indeed, as indicated under *Uromyces heterodermus*, a group of hosts may bear a number of rusts of various life cycles, belonging to *Puccinia* and *Uromyces*, widely distributed geographically, yet all showing a certain unanimity of morphological characters, especially in the telial stage.

The writer wishes to express his keen appreciation to Dr. J. C. Arthur for suggesting this paper and for much help, and also to Professor Jackson for many suggestions and constructive criticism. To the other workers in the laboratory at Purdue University he is likewise greatly indebted.

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St. Paul, Minn.

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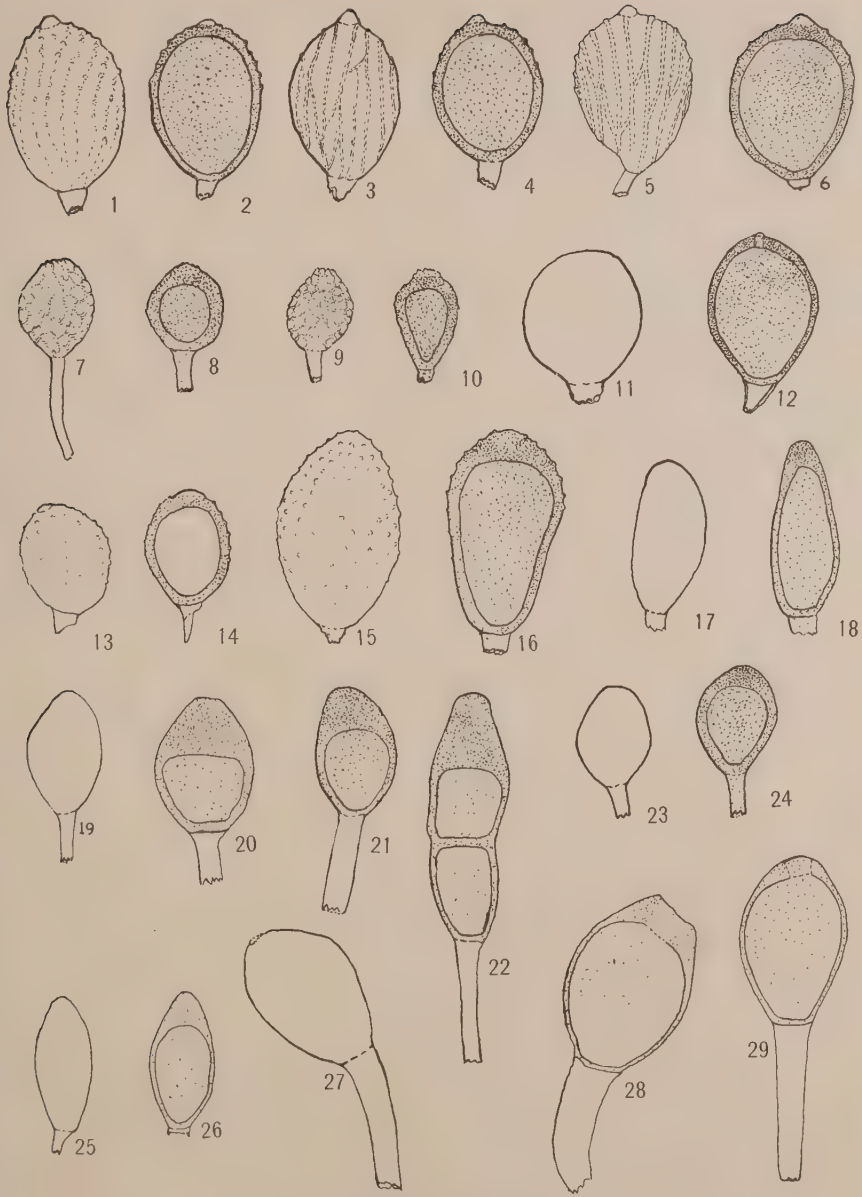
EXPLANATION OF PLATE X

All figures were drawn at the level of the stage with the aid of a camera lucida, with Leitz 1/12 oil immersion and ocular 4. They are here reduced one-third, so that the magnification is 667 diameters. Surface markings, where present, are indicated, and the stippling on the optical cross-section diagrams



BISBY on UROMYCES

represents to some degree the comparative darkness of color of the spore walls. In most cases the drawings of short cycle *Uromyces* were made from type material.

FIGS. 1, 2.—Surface and optical cross-section, respectively, of teliospores of *Uromyces heterodermus* Syd., from type material, on *Erythronium parviflorum*, Wasatch Mountains, Salt Lake County, Utah; A. O. Garrett, Fungi Utahensis *118*.

FIGS. 3, 4.—*Uromyces Erythronii* (DC.) Pass. on *Erythronium dens-canis*, Bohemia. Sydow, Ured. *1505;* species correlated with preceding.

FIGS. 5, 6.—*Uromyces Holwayi* Lagerh. on *Lilium columbianum*, Washington. Barth., N.A. Ured. *1387;* compare two preceding species.

FIGS. 7, 8.—*Uromyces bauhiniicola* Arth., from type material on *Bauhinia Pringlei*, Guadalajara, Mexico.

FIGS. 9, 10.—*Uromyces jamaicensis* Vesterg., from type material, on *Bauhinia* sp., Constant Spring, Jamaica.

FIGS. 11, 12.—*Uromyces abbreviatus* Arth., from type material, on *Psorlea Purshii*, Winnemucca, Nevada. Griffith, W.Am. Fungi *390*.

FIGS. 13, 14.—*Uromyces Tranzschelii* Sydow, from type material, on *Tithymalus* (*Euphorbia*) *montana*, Fossil Creek, Colorado. Ellis and Everhart, Fungi Columbiana *1069*.

FIGS. 15, 16.—*Uromyces nevadensis* Hark., from type material, on *Primula suffrutescens*, near Lake Tahoe, Nevada.

FIGS. 17, 18.—*Uromyces Myrsines* Diet. on *Ardisia compressa*, south of Cartago, Costa Rica.

FIGS. 19, 20.—*Uromyces Solidaginis* (Sommerf.) Niessl. on *Solidago serotina*, Helena, Montana. Ellis and Everhart, N.A. Fungi *2883*.

FIG. 21.—*Uromyces Solidaginis* on *Solidago virgaurea*, Sweden. Sydow, Ured. *2406*.

FIG. 22.—*Puccinia Asteris* Duby on *Aster adscedens*, Salt Lake County, Utah, illustrating correlation with *Uromyces Solidaginis*.

FIGS. 23, 24.—*Uromyces amoenus* Sydow, from type material, on *Anaphalis subalpina*, Paradise Valley, Mount Tacoma, Washington.

FIGS. 25, 26.—*Uromyces Rudbeckiae* Arth. and Holw., from type material, on *Rudbeckia laciniata*, Decorah, Iowa.

FIGS. 27, 29.—*Uromyces Bidentis* Lagerh. on *Bidens pilosa*, Ponce, Porto Rico, from type material of *Uromyces densus* Arth.

FIG. 28.—*Uromyces Bidentis* from material from type locality on *Bidens andicola*, Ecuador.

Give Seed Potatoes Every Chance[1]

Treatment of Seed Worth While—What It Accomplishes and How It Is Done

By G. R. BISBY,
Minnesota Agricultural Experiment Station

THE USE of corrosive sublimate or other substances for the treatment of potato tubers has become quite general with growers, especially those who produce seed potatoes, or grow potatoes on an extensive scale. The facts presented in this paper are based very largely on experiments and observations made in Minnesota during the past few years.

Potato seed treatment is designed especially to kill the black scurf and scab organisms on the tubers. Certain other diseases are also decreased, and the disinfection is a good general sanitary measure. Some growers attribute striking results to treatment; others claim that no benefit ensues. The truth lies somewhere between these two extremes and most of those who have treated potatoes consistently appreciate its advantage. It must be remembered that the fungi which cause both scab and black scurf or dry stem rot are present in most soils, so that seed treatment does not guarantee a perfectly clean crop. It also is evident, on the other hand, that there is much greater danger of infection if quantities of the casual organisms are planted in a live condition with the seed pieces where they can easily infect the young stems and tubers which will develop.

Soil type exerts a great influence on the occurrence of black scurf and scab. Temperature and weather conditions also exert considerable influence. It is well known that scab does not ordinarily occur in acid soils. One of the best methods, therefore, of reducing scab is that of plowing under a cover crop, which increases slightly the acidity of the soil. This fits in with the best rotation practices, in which a crop of clover or alfalfa is plowed under in the field to be used for potatoes. On the other hand, the use of lime or manure tends to make the soil more alkaline, and potatoes should not be planted on such soils for a year or two, unless they naturally contain sufficient acid to neutralize the alkalinity added. Because of the alkalinity of wood ashes, scab is much more likely to be severe when potatoes are planted on cleared land where wood has been burned.

Black scurf and dry stem rot (*Rhizoctonia*) are common especially in certain heavier soils. While good yields may be obtained, sometimes 90 per cent of the tubers show the black scurf. In many of these soils crops of potatoes are planted every two, three, or four years, and this repetition of potato crops results in an accumulation of the Rhizoctonia fungus which makes it difficult to grow a crop without a high percentage of black scurf. Seed treatment must be combined, in such cases, with longer and better rotations.

Common scab seriously affects the appearance and salability of potatoes. Black scurf produces a more superficial blemish, and is frequently considered to be merely dirt. Planting tubers with common scab without disinfection simply increases the danger of the scab in the crop; planting untreated tubers with black scurf not only increases the liability of black scurf on the tubers produced, but increases the danger of injury to the growing plants from dry stem rot.

(*Continued on page 28.*)

[1]Published with the approva' of the Director as Paper No. 67 of the miscellaneous series of the Minnesota Agricultural Experiment Station.

light-proof boxes at night and not uncovered until the sun is about half an hour high each morning during the summer time, violets can be forced to bloom again in the summer. Spring flowers and spring crops happen to be spring flowers and spring crops because the days at the season of their flowering and fruiting have the proper number of hours of daylight. Correspondingly, the early summer flowers and crops must have a longer period of daylight. This has been proved as to a large number of plants, and the scientists believe that the principle will hold throughout the higher forms of plant life, and that it is probably applicable to animal life as well.

The plant can not attain sexual reproduction, it has been shown, except when it is exposed to a favorable length of day. The requirements, however, differ widely with species and varieties. But a length of day that is unfavorable to reproduction may be favorable to growth. Under that condition the plant continues its vegetative development profusely and indefinitely without bearing fruit. A length of day may be found that is favorable both to sexual reproduction and vegetative growth. That tends to bring about the "everbearing" type of fruiting.

By employing dark chambers to shorten the period of light and artificial lights to extend it, scientists of the Department have shortened or lengthened the life cycle of plants, have made some of them complete two cycles in a single season, have brought others into flower and fruit months in advance of their regular time and, with still others, have greatly delayed

The results were the same, even when the temperature was higher in the dark house than on the outside. Another striking illustration of the relative unimportance of temperature is the fact that plants kept in the dark for a part of the day underwent, in midsummer, the changes that in nature come in the fall and have always been attributed to lower temperatures. This, also, was true even when the dark houses registered a higher temperature than that of the outside summer atmosphere.

Long vs. Short Hours of Light

The results obtained by artificially extending the period of light are just as interesting as those obtained by artificially shortening it. The artificial illumination, in a test with iris, was so arranged as to give 18 hours of continuous light in a greenhouse during the winter. Control plants were kept in a similar greenhouse with no artificial light. The test was begun on October 20, 1919. In the greenhouse where daylight was supplemented with electric light, the plants made rapid growth, soon attained normal size and produced blossoms on December 24. The plants in the greenhouse where no artificial light was used, though it was kept at the same temperature, remained practically dormant and showed no tendency to blossom as late as February 12, 1920.

The influence of this discovery on crop yields is likely to be of no little importance. The length of day is proved to be the most potent factor in determining the relative proportions

(*Continued on page 38.*)

Circular No. 52—Third Edition July, 1920

MANITOBA DEPARTMENT OF AGRICULTURE

Potato Top Diseases

—IN—

July and August

Healthy Plant with Leaf Roll on either side

By V. W. JACKSON and G. R. BISBY
Manitoba Agricultural College
Winnipeg, Manitoba

The Botany Department, Manitoba Agricultural College, Winnipeg, Manitoba, will be glad to obtain specimens of diseases of potatoes, or of other crops, and to give further advice about the prevention of disease.

Potato Top Diseases in July and August

Manitoba potato growers suffer large losses each year from injury to the crop from diseases. Most of the diseases affecting the vines can best be seen at about the time they blossom. It pays to examine the plants carefully for diseases during the summer, and to take measures to avoid them. If Manitoba will grow disease-free potatoes, they will be in demand for seed purposes.

The following diseases should be watched for this summer:

"RUNNING-OUT" DISEASES

Mosaic, Mosaic Dwarf or Curly Dwarf, and Leaf Roll bring about conditions commonly spoken of as "running-out."

Leaf Roll may be recognized by the upward rolling of the leaves. The lower leaves are affected first, and most seriously. The diseased plants are smaller than normal, and the leaves are crisp, rigid and brittle, so that they rattle when brushed. The whole plant has an erect, stiff and slightly yellowish appearance. Few potatoes are formed, and these are set close to the stem.

Typical Leaf Roll with clustered tubers

Mosaic is distinguished by a mottling of lighter green with the darker, normal green of the potato leaves. This mottling is not always found, but the leaves may show, instead, a crinkled, corrugated appearance. In more severe cases, the whole plant becomes unthrifty and dwarfed, and the term **Mosaic Dwarf,** or **Curly Dwarf,** is applied. The affected plants set fewer potatoes than normal plants, and these potatoes are sure to carry the disease when they are planted the next year.

A Green Mountain Potato affected with Mosaic. Photo by Murphy.

The lower leaves may die and drop off sometimes on plants affected by a dwarf disease similar to Mosaic.

These "Running-Out" diseases mentioned are carried over from year to year by planting potatoes that were produced by affected plants. It has also recently been shown that insects, such as plant lice, may

Clusters of tubers formed at the surface of the ground after the parts below had been badly injured by Rhizoctonia

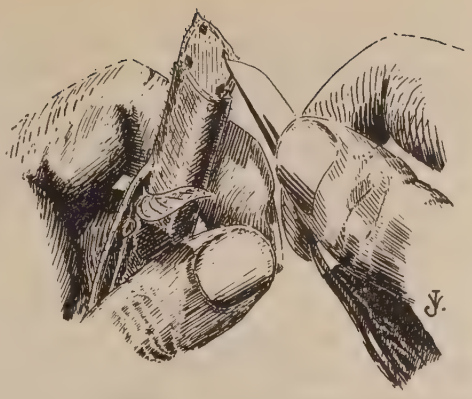
HOW TO AVOID TOP DISEASES

The best time to begin to avoid disease next year is this summer and fall. When the potatoes are in bloom, set aside the best part of the field from which to obtain seed for next year, provided there is not a considerable mixture of varieties, or percentage of diseases. If you are convinced that the kind of potatoes you are growing cannot be made the best in the neighborhood, do not use them for seed, but later obtain a stock of good vigorous potatoes for next year. However, if you have a good lot of potatoes, go carefully over the part of the field that you have set apart for seed, and remove the mixed varieties, and the weak and diseased plants. Then, just before frost, in the fall, it is an excellent plan to practice **Hill Selection;** that is, dig up the best looking hills by hand, and if there are a number of good-looking, healthy potatoes under a hill, save them to plant in a seed plot the next year. This seed plot, which need be only one-twentieth the size of the field, is to produce the seed for the year after. After you have selected the best hills for a seed plot, dig the rest for seed for the general field next year. It pays to plant the best potatoes that can be obtained, for "like produces like," in potatoes as in everything else. There are few crops that will give such good results as potatoes will from selection and care.

Spindly Sprout (on left) due to poor or small set

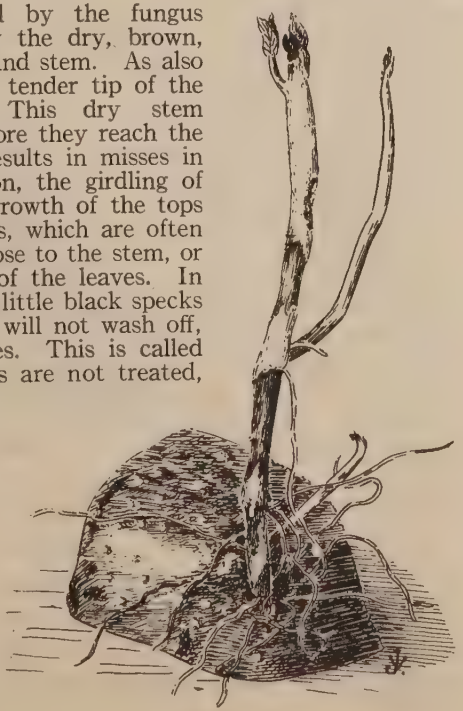
When the potatoes are dug, store them in a clean, cool and dry place over winter. If the cellar, or bin, is cleaned out thoroughly, there will be less danger of rot. In the spring remove all rotted, imperfect potatoes before cutting them for seed.

Wilt occurs as a result of the stoppage of the water tubes in the lower stem. When the stem is cut across, a brown ring will be seen. In severe cases, the stem below the ground may become brown throughout. Affected plants droop, wilt, turn yellowish, and often die. Wilt attacks all varieties, but does not usually occur until rather late in the season, so that a fair crop of potatoes may be produced. These potatoes may, however, also show a brown ring in the stem end, and should not be used for seed. The provision of good growing conditions will enable the plants to resist the disease.



Four Brown stems in a cut stem indicates Fusarium Wilt

Dry Stem Rot, caused by the fungus Rhizoctonia, is recognized by the dry, brown, sunken spots on the underground stem. As also shown in the illustration, the tender tip of the sprout may be attacked. This dry stem rot often kills the sprouts before they reach the surface of the ground, and results in misses in the field. Later in the season, the girdling of the plant may result in overgrowth of the tops at the expense of the potatoes, which are often small and irregular, and set close to the stem, or may even occur in the axils of the leaves. In the fall the fungus gathers as little black specks that look like dirt, but which will not wash off, on the surface of the potatoes. This is called **Black Scurf.** If the potatoes are not treated, the dry stem rot may be expected when such seed is used.



Dry Stem Rot

LEAF DISEASES

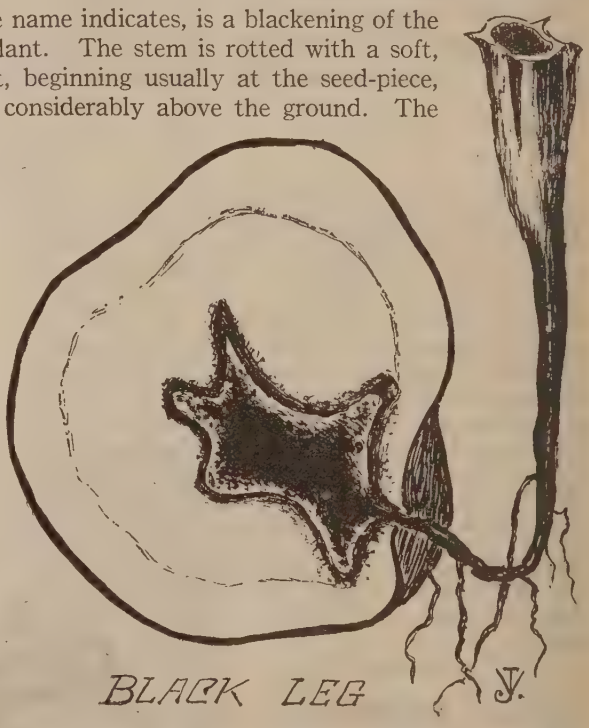
Late Blight, Early Blight, and Tipburn, are characterized by spots on the leaves, but the records do not indicate that they are serious in this province.

spread the diseases from plant to plant in the field, or the roots of diseased plants may come in contact with healthy roots and thus spread the disease. The diseases are rather slow in making their appearance on affected plants, so that one cannot be sure that the plants are healthy unless there are no affected plants nearby. It is, therefore, important to select seed from fields which show uniform, healthy, vigorous plants. If a lot of potatoes contains much of these "Running-Out" diseases, it would pay to dispose of it and obtain a new stock that is vigorous and free from disease.

STEM DISEASES

There are three diseases that may be found attacking potato stems in Manitoba: Blackleg, Wilt, and Dry Stem Rot or Rhizoctonia.

Blackleg, as the name indicates, is a blackening of the lower stem of the plant. The stem is rotted with a soft, inky-black, slimy rot, beginning usually at the seed-piece, and extending often considerably above the ground. The rotted stem may, later, dry out and appear brown. The whole plant becomes yellow, then wilts, and usually dies. The young potatoes of affected plants are often rotted, beginning at the stem end, with a soft, foul-smelling, slimy rot. Such affected potatoes should not be put in the bin with healthy potatoes, for the rot will spread in storage, and the disease may be produced again if such potatoes are used for seed. All varieties are affected, and the disease is worst in cool, moist seasons. Besides removing plants showing blackleg from the part of the field from which seed is to be saved, it is a good plan to treat the potatoes before planting with a solution of formaldehyde or corrosive sublimate.



BULLETIN 190 JUNE 1920

The University of Minnesota

AGRICULTURAL EXPERIMENT STATION

POTATO DISEASES IN MINNESOTA

BY

G. R. BISBY

DIVISION OF PLANT PATHOLOGY AND BOTANY

AND

A. G. TOLAAS

IN CHARGE OF POTATO SEED CERTIFICATION

UNIVERSITY FARM, ST. PAUL

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SUMMARY

Diseases cause a loss of from four to six million bushels of potatoes in Minnesota each year. Much of this loss can be prevented by proper control measures.

Varieties of potatoes best adapted to the locality should be grown. A vigorous, healthy strain of the variety should be obtained. Use certified seed.

The health and vigor of the stock should be kept up by selection and the use of seed plots.

Plots grown for seed should be rogued to remove varietal mixtures, weak plants, and those affected with black leg, mosaic, or leaf roll.

Seed potatoes affected with scab, black scurf, or other surface infection, or which have been exposed to infection in bins or other containers, should be disinfected.

Crop rotation and other good agricultural practices will result in increased yield and less disease.

Spraying the plants with bordeaux mixture will largely control leaf diseases and will increase the yield.

Seed potatoes should not be selected from fields which show a considerable percentage of weak plants or of mosaic, leaf roll, and other diseases, or of varietal mixture. If diseases affect the stock grown, obtain a new strain that is clean—obtain certified potatoes. Keep up the vigor of the new strain by seed plots and other measures mentioned.

The crop should be handled carefully at digging time and after the potatoes are harvested in order to avoid bruises and cuts, from which rots develop.

The potatoes should not be exposed to temperatures below freezing or to high temperatures.

The storage cellar should be clean, well ventilated, and cool.

If possible, prevent the development of sprouts on seed potatoes, since considerable loss of vitality results when these break off.

Prevent the introduction of new diseases and control those already present. This will pay. Better agricultural practices include the control of diseases.

POTATO DISEASES IN MINNESOTA

By G. R. Bisby and A. G. Tolaas

INTRODUCTION

Potato diseases cause losses totaling from four to six million bushels or more of potatoes each year in Minnesota. Much of this loss is preventable. The interest shown by growers during the last few years indicates that there is a continually growing realization of the seriousness of potato diseases, and more intelligent efforts are being made to prevent them. Minnesota Bulletin 158, "Potato Diseases and Their Control" by E. C. Stakman and A. G. Tolaas, has been out of print for some time, and as there is a considerable demand for information on the various diseases and control methods, this bulletin is prepared as a revision of bulletin 158.

After preliminary experimental work at University Farm, a campaign was started coöperatively by the Division of Agricultural Extension and the Section of Plant Pathology to reduce losses from potato diseases and to improve the potato crop in general. This work was performed largely through the use of the seed plot method and will be discussed later. In 1919 the Legislature created the Minnesota Board for Seed Potato Inspection and Certification. The object was to recognize the work that had been done by many growers in improving their seed stock and to give Minnesota growers and southern users of Minnesota seed potatoes an opportunity to obtain pure, disease-free seed. This has emphasized the necessity for knowing and preventing diseases.

While potato diseases cause great losses in Minnesota, the situation here is no worse than in other states; on the contrary, Minnesota is fortunate in the infrequency of serious attacks of late blight and other diseases, and has a climate particularly favorable to the growth of potatoes. Powdery scab, feared when first found here, has not proved serious. The recent discovery of potato wart in the eastern states has made it imperative, however, that the introduction of this and other serious diseases be constantly guarded against.

Most potato diseases are caused by fungi, which are organisms that grow on or in portions of the plant. Some are caused by bacteria, and a few, such as frost injury, by the effect of weather. It may be emphasized that while most diseases occur only when weather conditions are favorable, it is the living parasite, not the weather, which causes the disease. No known potato disease will injure persons or animals.

Following the practice in bulletin 158, diseases are grouped according to the part of the plant attacked, with a brief outline of control measures. The consideration of specific diseases is followed by a discussion of general control measures. Many details are omitted, and growers are urged to write to the Section of Plant Pathology, University Farm, St. Paul, for further information or for identification of diseases of potatoes or other crops. Specimens should be sent if identification is desired.

KEY TO DISEASES

Leaf diseases
- Leaves only affected
  - Diseased spots scattered, roundish, dry.....Early blight
  - Diseased area on tip or margin of leaf.....Tipburn
- Leaves or stems affected with brown spots.....Arsenical injury
- Leaves, tubers and often stems affected.
  - Spots on leaves scattered, irregular, watersoaked when wet..Late blight
- Whole plant affected, leaves mottled, curled or rolled.....See Mosaic

Mosaic and similar diseases
- Leaves mottled, especially when young, crinkled more or less.....Mosaic
- Leaves badly crinkled, plants much dwarfed.....Mosaic dwarf
- Lower leaves rolled, crisp.....Leaf roll

Stem diseases, tubers also often affected
- Lower stem rotted, black, slimy at first; tubers soft rotted.....Blackleg
- Stems browned internally; brown ring in tubers.....Wilt
- Lower stem with dry brown scars; black masses on tubers.....Rhizoctonia
- Stems dying rapidly in small area.....Lightning injury

Parasitic tuber diseases
- Roundish corky spots, skin not torn at edge.....Common scab
- Roundish powdery spots, small, skin torn at edge.....Powdery scab
- Wart-like swellings from eyes and elsewhere.....Black wart
- Irregular silvery patches on tubers.....Silver scurf
- Black "shoestring" threads on surface.....Honey mushroom
- Black scurf on tubers, or stem end browning, see Rhizoctonia and Wilt.
- Rots of tubers
  - Rot in storage, usually following wounds, dry.....Fusarium rot
  - (See also Late blight dry rot, Blackleg soft rot)

Non-parasitic tuber diseases
- Tubers soft, or discolored internally.....Freezing injury
- Tubers green outside and somewhat inside.....Sunburn
- Black areas inside tubers.....Black heart
- Brown netted or irregular spots inside...Net necrosis, Internal brown spot
- Hollow area near center of tubers.....Hollow heart
- Rootstalks of quack grass penetrating tubers.....Quack grass injury
- Tubers producing many small sprouts.....Witches' broom
- Tubers producing weak, spindling sprouts.....Spindling sprout
- Tubers producing tubers instead of tops from sprouts....."No tops"
- Tubers producing weak, low yielding plants....."Running out"

LEAF DISEASES

Early Blight, caused by *Alternaria solani*

Early blight is common, and reduces the yield by injuring the leaves. The vines may die early if the leaves are seriously affected. The spots occur on any portion of the leaf, often exhibit concentric markings, and are brown and dry. See Figure 1. The spots are usually more or less circular, 1-8 to 1-4 inch in diameter, and may unite. The stems and tubers are not affected directly. The disease is worse when high temperatures alternate with moist periods. The fungus overwinters on the dead potato vines.

Fig. 1. Early Blight (left) and Hopperburn (right) of plants

The disease can be lessened by crop rotation and by the destruction of old vines, and especially by spraying throughout the season with a 5:5:50 bordeaux mixture, as discussed later.

Tipburn (Hopperburn and Sunscald)

The condition in which the margins and tips of the potato leaves turn brown and die was formerly commonly attributed to the effect of

hot dry weather. While it is true that the potato plant does not stand hot weather well, it has been shown by Ball (1) and others that leaf-hoppers are responsible for much of this burning. When leaf-hoppers produce the burning, the veins are most seriously affected, that is, the browning extends along the veins of the leaf. This burning has been called hopperburn, and is shown in Figure 1. The effect of hot weather alone is manifested by the most serious injury to the leaf tissue between the veins. Tipburn is distinguishable from other leaf diseases by the fact that the injury involves the margin of the leaf. The damage to the crop, as in early blight, comes from the reduction in leaf area, resulting often in premature death of the plants.

Spraying with bordeaux mixture lessens the liability to injury from this, as well as from other leaf diseases. Bordeaux mixture is valuable in keeping leaf-hoppers off the vines. Work is being done by the Department of Entomology looking to the further control of leaf-hoppers.

ARSENICAL INJURY

Often when paris green, arsenate of lead, or other poison is applied to the potato plant in too great strength, spotting of the leaves or stems may occur. These spots commonly start from wounds, such as insect injuries, on the leaves. On the stems the injury is commonly found at the axils of the leaves or branches where the poison has collected.

If the poison is applied with bordeaux mixture, the lime present will prevent injury. The use of high pressure sprayers will lessen the liability of the accumulation of large quantities of poison on the plants. A little lime added to the poison will neutralize the burning properties of the arsenic. In any case arsenical injury is not often serious.

Late Blight and Rot, caused by *Phytophthora infestans*

Late blight is one of the most destructive of potato diseases. The fungus attacks leaves, stems, and tubers. Fortunately this disease is not often serious in Minnesota, altho it may sometimes occur in epidemic form and completely destroy fields if they are not protected by thoro spraying.

Irregular spots without definite margins are produced on the leaves. In damp weather these areas are dark and water-soaked, and are covered below with a moldy growth. In dry weather these spots dry out and appear brown. The leaves may be destroyed very rapidly, and even the stems may be attacked. The fungus may be washed from the leaves of the plant through the soil to the tubers, and start a rot which spreads in the field and then in storage. (See Figure 2.)

Sometimes the tubers are infected at digging time by coming in contact with the diseased tops. This rot is brown and watery when the potato is dug, or when it remains in a moist place, and the surface is sunken and lead-colored, with a rather definite brown margin. Late blight rot should not be confused with blackleg rot, which is soft and slimy; or with Fusarium rots, which are ordinarily dry rots, and develop particularly after the potatoes have been dug. Late blight rot

Fig. 2. Late Blight Rot on Tubers
Above, external view showing sunken diseased areas; below, section showing dry rot.

develops in the field, especially on the side of the tuber which was uppermost in the soil. After the tubers are harvested the rot may continue in the bin or in cars, and may be followed by attacks of other rotting organisms, so that sometimes whole bins of potatoes are destroyed. The fungus often remains alive in the tuber through the winter, and when affected seed pieces are planted, the fungus may grow up the shoot to the vines and start a new epidemic of the disease.

The development of late blight depends on weather conditions. Cool, wet weather in July or early August followed by damp weather in August, is favorable to the development of the disease. Dry weather, on the other hand, checks it.

While the disease is usually not serious in Minnesota, it was very destructive in 1914 and 1915, and caused some damage in the southern part of the state in 1918. Usually it is more likely to be serious in northern Minnesota.

Late blight can be prevented by spraying with 5:5:50 bordeaux mixture, beginning in late July and keeping the mixture on the vines until the end of the growing season. Spraying is an insurance against late blight and pays for itself in increased yield even if late blight is absent. Never plant potatoes from fields which showed late blight. If the disease occurs on the vines, postpone digging until the tops have died and dried up, and keep the potatoes in cool, dry, well-ventilated storage.

MOSAIC AND SIMILAR DISEASES

Mosaic, leaf roll, and curly dwarf or mosaic dwarf have been attracting the attention of potato growers and of plant pathologists in the last few years. These are probably not new diseases, but are at least in part the cause of what was formerly simply called "running out." The whole plant is affected, altho the symptoms are apparent only on the leaves, and the diseases are transmitted to new plants by diseased seed tubers.

Mosaic

In Minnesota mosaic is especially common on Bliss Triumph altho it occurs to some extent also on other varieties. Diseased leaves show a mottling of lighter green with the darker, normal green of the leaves. This symptom is often visible only when the plants are young, and may sometimes be masked entirely in this region. The leaves are commonly crinkled, particularly later in the season, and if the disease is severe, the plant appears dwarfed and unthrifty. Figure 3 illustrates the general appearance of healthy and diseased plants.

Altho mild attacks of the disease may not reduce the yield greatly, in Minnesota, the loss is very serious when affected tubers are sent south for seed. The disease is spread from plant to plant by insects (2), or by roots of diseased plants coming in contact with healthy roots (3). The signs of infection are slow in appearing, however, and may not show until tubers are planted and produce new vines. Selection must therefore be made from fields in which little or no disease occurs, and such fields of the Triumph variety are rare.

Fig. 3. Mosaic and Healthy Plants

Spraying or seed treatment will not prevent this disease. Efforts are being made to obtain and distribute mosaic-free Triumph stock. The most satisfactory method of eradicating mosaic from other varieties is to obtain more vigorous strains if the stock grown is unsatisfactory. The disease evidently does not live over winter in the soil. The use of seed plots and seed selection helps to lessen such diseases as mosaic.

Mosaic Dwarf

When the potato plants are seriously affected with mosaic they may become badly dwarfed, as illustrated in Figure 4. This condition is called mosaic dwarf, and the yield is much reduced. When tubers from plants which show only slight mosaic in Minnesota are sent south for seed purposes, the resulting plants yield very poorly, and for this reason only a limited certificate was given to practically

all Triumphs listed for certification in 1919. The mosaic dwarf sometimes appears also under conditions found in this state. The disease known as curly dwarf is the same or similar.

Fig. 4. Mosaic Dwarf in Field

Leaf-roll

Leaf-roll is similar in nature to mosaic, altho the symptoms are quite different (4). The lower leaves in particular are rolled upward on the midrib, and are more rigid than usual. Diseased plants are smaller than normal, and are slightly yellowish in color. The tubers are set close to the stem, and the yield is much reduced. Figure 5 shows the rolling of the leaves.

Fig. 5. Leaf Roll

The rolling of the leaves should not be confused with the rolling caused by Fusarium wilt, blackleg, or dry stem rot. There is not a

wilting of the leaves in the case of leaf-roll, but they remain rigid even in dry weather, and there is no browning caused by the disease on or in the stems of the plants. The phloem of the affected plants is injured, and the term "phloem necrosis" is often applied to leaf roll.

Fig. 6. Blackleg on Vines
Note blackened portion near the base.

Fortunately, leaf roll has not been common in Minnesota fields. It has, however, been quite abundant in some sections of the eastern potato-growing regions. Growers should avoid the use of all seed from fields showing the disease.

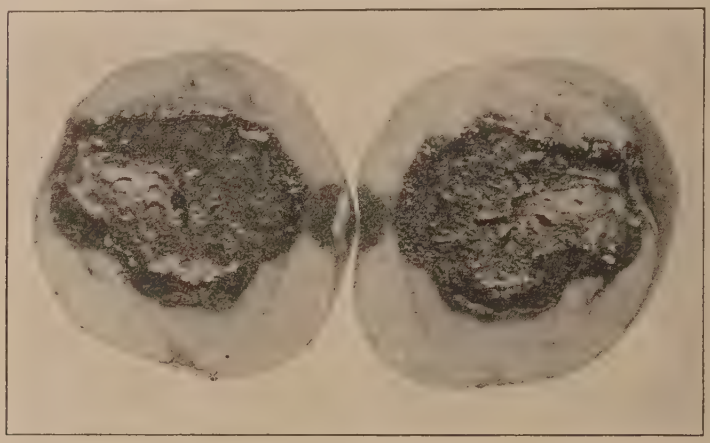

Fig. 7. Blackleg on Tubers

STEM DISEASES

Blackleg, caused by *Bacillus atrosepticus*

Blackleg disease affects both the stems and the tubers. On the stems it appears as an inky-black discoloration or rot near the surface of the ground, beginning usually at the point of attachment to the old seed-piece. See Figure 6. This seed piece practically always is rotted. The disease may extend upward in the stem, altho it often ceases at about the ground line. While the disease is spreading the affected area is usually soft and slimy; later the stem may dry out. The whole plant becomes yellow, wilts, and usually dies. The rot may extend down the stolons to the tubers, and set up a soft, foul-smelling rot, shown in Figure 7. Often the plant is killed before tubers have formed.

Blackleg is one of the important diseases in Minnesota. It is worse in cool and moist seasons (5). The disease probably overwinters in affected tubers, since experiments have failed to show that the organism survives the winter in the soil. Care should therefore be taken not to use affected tubers, and the diseased plants should be rogued from the field, as described later. Disinfecting the seed before planting is also a good precautionary measure.

Wilt, caused by *Fusarium oxysporum*

The fungus causing wilt is common in Minnesota soils (6). Serious damage does not occur, however, unless the vigor of the potato

plant is reduced by high temperature or other unfavorable conditions. The fungus can live for a long time in the soil; indeed, it occurs naturally in some soils. It may also be planted with tubers affected with ring discoloration.

Affected plants droop, the leaves roll up and become flabby, the vines become yellowish and finally die. See Figure 8. The sap tube

Fig. 8. Fusarium Wilt

area of the lower stem is browned, as may be observed by cutting the stem. In extreme cases the whole lower stem may rot with a brown rot. The roots often rot, and the fungus may pass through the stolons into the developing tubers, causing the ring discoloration near the stem end, as shown in Figure 9. Occasionally a rot caused by the same fungus or other fungi begins at the stem end. This stem end browning should not be confused with net necrosis (Figure 19) or with certain types of frost injury (Figure 17).

Fortunately, wilt does not commonly occur in Minnesota until rather late in the season so that the yield is not often seriously reduced. As vigorous plants are able to resist the action of the fungus, good growing conditions should be maintained. Rotation of crops, besides affording better growing conditions, avoids the accumulation of this and other fungi in the soil. It is a common practice to cut

about half an inch off the stem end of the potato when cutting seed, and to discard this slice. This often reduces the danger of infecting new plants.

Fig. 9. Ring Discoloration

Dry Stem Rot and **Black Scurf**, caused by *Rhizoctonia solani*

A variety of symptoms may be produced on potato plants by Rhizoctonia. Dry stem rot and black scurf of the tubers are the most common symptoms, altho "rosette," "little potato," "big vines and no potatoes," and "russet scab" indicate other symptoms of the disease. The fungus attacks the stems below the ground line, and causes the greatest damage to the young sprouts, as shown in Figure 10. These sprouts may be killed, and when secondary sprouts are produced these also may be attacked, so that the plant may not get above ground, or at least it is weakened. Much of the reduction in stand may be attributed to Rhizoctonia. Dry stem rot appears as a browning of definite areas on the surface of the underground stem. Older plants may be attacked and girdled, and large, bushy vines bearing small aerial potatoes in the axils of the leaves and branches frequently are produced. Many small irregular tubers are often produced close to the underground stem as a result of the disease rotting off the stolons. Affected plants may show some wilting.

On the tubers, the disease known as black scurf, shown in Figure 11, is produced. This scurf is often mistaken for "dirt that won't wash off" but is composed of compact masses of the fungus adhering closely to the surface. It not only injures the appearance of the tubers, but

Fig. 10. Dry Stem Rot

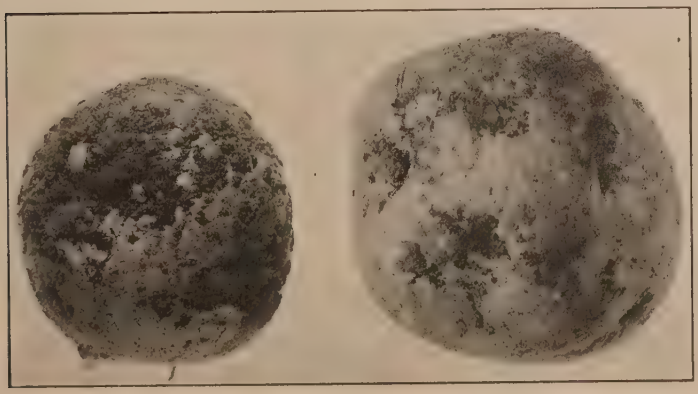

Fig. 11. Black Scurf on Tubers

such tubers should not be planted without disinfection. Sometimes a russet scab, attributed to Rhizoctonia, is produced on the tubers.

Dry stem rot causes an average loss of about two per cent of the potato crop of Minnesota each year. In some of the heavier soils black scurf is abundant almost every year.

The fungus occurs naturally in Minnesota soils, and it is difficult to eliminate the disease entirely. In spite of this fact, it is obvious that there will be much greater liability of dry stem rot on the young plant if large masses of fungus are planted with the seed tuber. Disinfection with corrosive-sublimate should be practiced. Rotation of crops will lessen the damage from the disease.

LIGHTNING INJURY

It has been observed recently that when lightning strikes in potato fields it may cause the sudden wilting and death of plants within a few feet or even within several rods of the point where the lightning struck. This should be remembered when seeking an explanation for rapid death of plants in small areas.

PARASITIC TUBER DISEASES

Several potato diseases affect the tubers directly. Any disease which causes appreciable injury to the plants also affects the tubers, at least in size or number. Most of the tuber diseases are caused by definite plant parasites. The effect of late blight, wilt, blackleg, and dry stem rot organisms has already been mentioned. Certain other parasitic troubles affecting only the tubers, either in the field or after the crop is dug, will here be considered, followed by brief discussions of certain non-parasitic diseases of the tubers.

Common Scab, caused by *Actinomyces scabies*

Scab is a common and well-known disease. The scabbed spots are illustrated in Figure 12. Sometimes the areas may extend rather deep into the tuber and in any case render it unsightly and less valuable for cooking or for seed. The scab spot is formed by the production of corky tissue so that the affected tuber does not ordinarily dry out or become infected by rotting organisms more easily than if scab were absent. Insects may invade the scab spots, however, and add to the injury. Deep injuries similar to scab may also be caused by wire worms or white grubs. The yield is ordinarily not diminished from the effect of scab. Recent work has shown that scab is worse when the temperature is high (8). Turnips, radishes, and beets are also sometimes affected.

The scab organism also occurs naturally in the soil, but scab does not occur when the soil has an acid reaction. Wood ashes, lime,

or fresh manure render the soil more alkaline and hence increase the amount of scab. Plowing under green crops tends to decrease scab.

Badly scabbed tubers should not be used for seed, since the eyes may be injured. Tubers with a slight amount of scab may safely be used if they are disinfected with formaldehyde or corrosive sublimate. It must be remembered that disinfection does not insure a clean crop of potatoes but lessens the liability of injury from the disease.

Fig. 12. Common Scab

Powdery Scab, caused by *Spongospora subterranea*

Powdery scab produces smaller spots than common scab, the edges of the spots are surrounded by the torn skin of the potato, and a brownish powder is found within the scabbed area. The appearance as contrasted with common scab is shown in Figure 13.

This disease, first found in this country a few years ago, was feared because of its seriousness in certain European countries. It has not, however, been found to cause much damage in the United States. The disease was found locally in 1915 in northeastern Minnesota, but it was not reported again until 1919, and then was not abundant. The disease, caused by a slime mold, occurs only in cooler and damper seasons, and does not develop in the south because the temperature is too high.

Affected potatoes should be sorted out and not planted. Disinfection with corrosive sublimate should be practiced if the disease has been found in a lot of potatoes to be used for seed. Because

the organism lives for several years in the soil, a rotation should be followed.

Fig. 13. Powdery Scab

Black Wart, caused by *Chrysophlyctis endobiotica*

Black wart has not been found in Minnesota. It has, however, appeared in certain regions in the eastern United States. A careful watch should be kept for this disease, and suspected tubers should be sent at once to the Section of Plant Pathology, University Farm, for examination. It is one of the most serious of potato diseases.

The disease, as shown in Figure 14, causes the development of irregular warty growths from the eyes or other parts of the tuber. These outgrowths may be as large as the tuber itself. They are whitish at first, then brownish, and finally black. They are spongy in consistency.

The fungus may live several years in the soil, and is spread by planting diseased tubers. Trash or soil from affected fields, peelings from diseased potatoes, or anything which has come in contact with diseased plants will carry the fungus. Great care must therefore be taken in regard to the source of tubers used for seed lest this or other diseases be introduced. This disease is common in Europe and imported potatoes should not be planted.

Silver Scurf, caused by *Spondylocladium atrovirens*

Silver scurf, characterized by silvery patches on the tuber, is not

of any great importance in Minnesota. Affected tubers may shrivel somewhat.

Injury by the Honey Mushroom *Armillaria mellea*

When potatoes are planted on newly cleared land the tubers may be attacked by threads of one of the fungi which rot the roots of

Fig. 14. Wart

trees. The fungus is found on the surface of the tuber as "shoestring-like" threads, as shown in Figure 15. While a rot of the tuber may occasionally follow, this is never a serious disease.

Fig. 15. Honey Mushroom Strands on Tuber

TUBER ROTS

The most serious losses to the potato crop each year come from tuber rots. If late blight occurs, it may result in great damage from rot, beginning in the field and continuing during storage or transportation. The blackleg rot may also begin in the field and spread after the potatoes are dug. Both these diseases have been discussed. In some years frost injury is severe in the field, in the bins, or in the cars, and rot commonly follows. Other storage rots also cause much damage, particularly to bruised potatoes.

Fusarium Dry Rot, caused by *F. discolor sulphureum* and other Fusaria

The dry rot which develops after the potatoes are dug is principally caused by the fungus Fusarium. (See also late blight rot.) This rot is brown, compact, and firm, with no foul odor, and affected tubers often contain cavities filled with a mold-like growth of the fungus. (See Figure 16.) This mold may also occur on the surface, particularly if the atmosphere is damp. The rot usually starts from a wound

Fig. 16. Fusarium Dry Rot

on the tuber, and may develop either slowly or rapidly, depending on temperature, moisture, and ventilation. Often as many as half of the potatoes are rotted by spring, and hundreds of reports from inspection of potatoes in transit show that the average loss is more than five per cent.

When tubers showing dry rot are planted, the rotting continues and may prevent the sprout from developing. Planting such tubers usually results in at least a weak sprout.

Greater care should be taken to prevent loss from dry rot. All possible precautions should be taken to avoid bruising, cutting, and otherwise breaking the skin of the potato, because it is through these injured areas that the rot almost always begins. Some injury to potatoes during digging and storing can not be avoided, but potatoes should not be handled like cobblestones. Clean storage should be provided; the bins should be cleaned out and disinfected thoroly before potatoes are put into them, since the fungus causing dry rot commonly lives over the summer on refuse in the storage bins. The bins should be cool (as near 35 degrees F. as possible), dry, and well ventilated.

The western powdery dry rot, caused by *Fusarium trichothecioides* has not been found in Minnesota.

Other Fusaria may sometimes cause rots, but they are not usually serious. Bacterial soft rots are quite common. Control measures mentioned above apply also for these rots.

Various organisms may complete the destruction of frozen potatoes. Frost injury is described below.

NON-PARASITIC TUBER DISEASES

Several diseases exerting an effect upon the tuber, and usually impairing its value for seed purposes, are included here. These diseases are not caused by parasites. Quack grass injury is accidental, and quack grass is not a parasite. Some of these diseases are very important; others of little significance.

Fig. 17. Frost Injury

Freezing Injury, Frost Necrosis (9)

Every year some damage results to the Minnesota potato crop from frost. When frost comes early in the autumn much injury may

occur in the field before or during digging. Considerable loss always occurs during the winter from freezing in the storage bins or in transportation.

When the tubers freeze solid, they become soft and wet upon thawing. Rots develop rapidly in such potatoes and may spread to other tubers if the frozen ones are not sorted out.

If the chilling has not been too severe, many of the potatoes may not show injury. When cut open, however, various ring and blotchy discolorations are found in the tissue, as shown in Figure 17. A ring

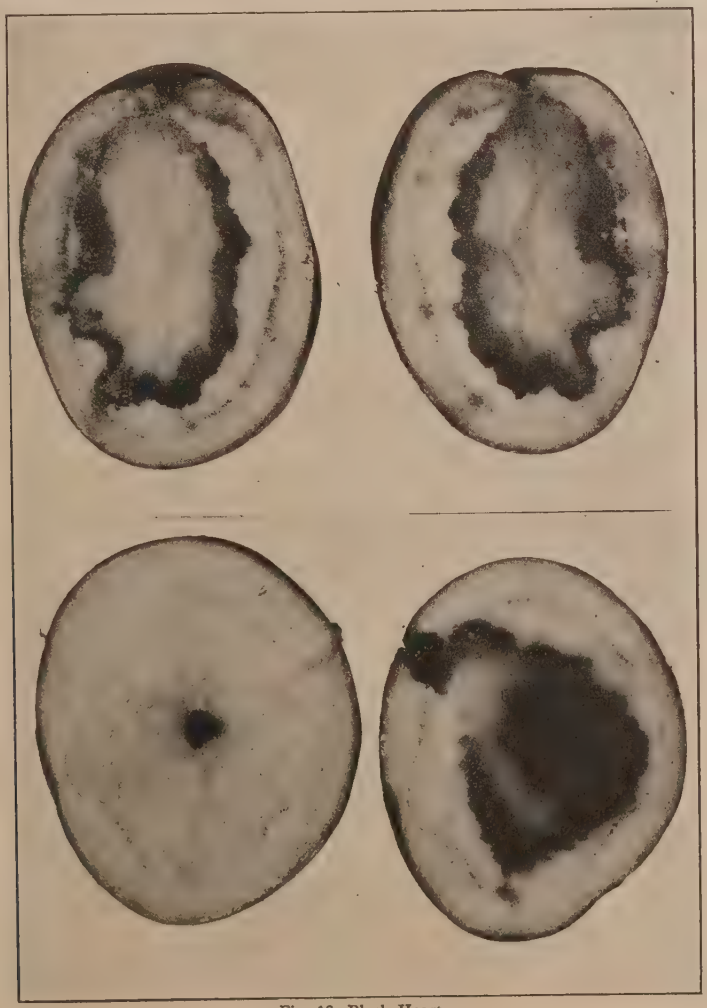

Fig. 18. Black Heart

discoloration is often produced which may resemble that produced by the wilt organism.

Frost injury usually can and should be prevented. If some of the tubers are frozen, they should be sorted out. In general, tubers showing any frost or other internal injury should not be used for seed.

Sunburn and Sunscald

The outside of potatoes which are exposed to light for some time either while growing or after digging becomes dark green in color. Sometimes the flesh also becomes green. Such tubers are bitter, and should not be eaten because they contain a poison.

Occasionally tubers exposed to brilliant sunshine in the field at digging time may be burned or scalded. This, however, rarely occurs in Minnesota.

Black Heart

Black heart is caused by exposure of potatoes to high temperature (100 to 113 degrees F.) from 14 to 48 hours, or by lack of air (10). The disease is found, therefore, in potatoes which have been overheated in cars during shipment, or in poorly ventilated bins in which the tubers have been piled too deep.

The flesh of affected tubers first becomes pink or purplish and then black. Such tubers are unfit for seed or table use. The remedy is ventilation in storage and the avoidance of overheating in shipping.

Fig. 19. Net Necrosis

Net Necrosis and Internal Brown Spot

Netted brown or blackish areas inside the potato, as shown in Figure 19, represent net necrosis. When the spots are larger and irregular, the condition is called internal brown spot. These diseases

apparently may result from unfavorable growing conditions or from a deficiency of some element in the soil. Probably much of this internal spotting is caused by exposure to cold. Affected tubers should not be used for seed.

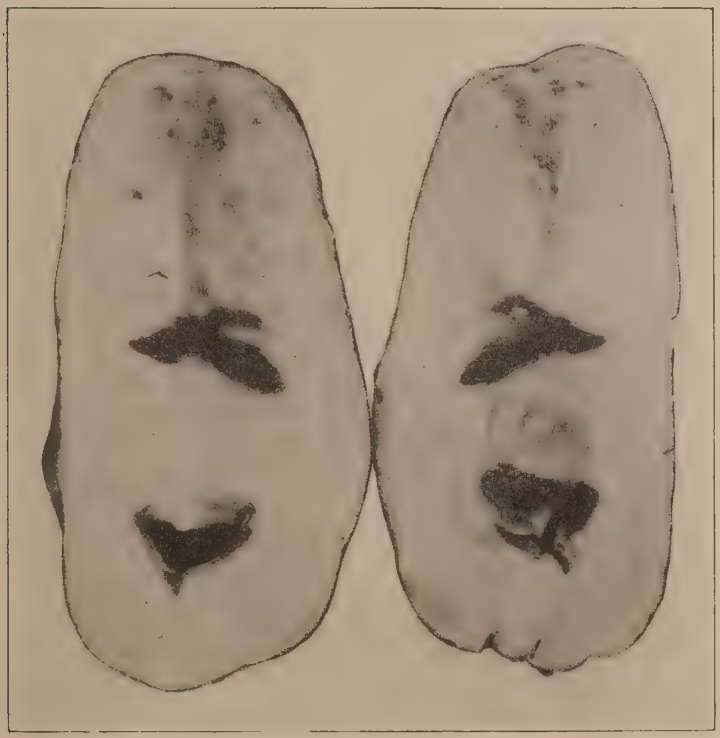

Fig. 20. Hollow Heart

Hollow Heart

When dry and wet periods alternate, or when tubers grow too fast, they may become hollow in the center. The tissue around the hollow areas is brown and corky (see Figure 20). Some varieties, as King and Rural New Yorker, are likely to produce hollow heart when grown on heavy, rich soil.

The trouble can be reduced by growing varieties adapted to the soil and by closer planting.

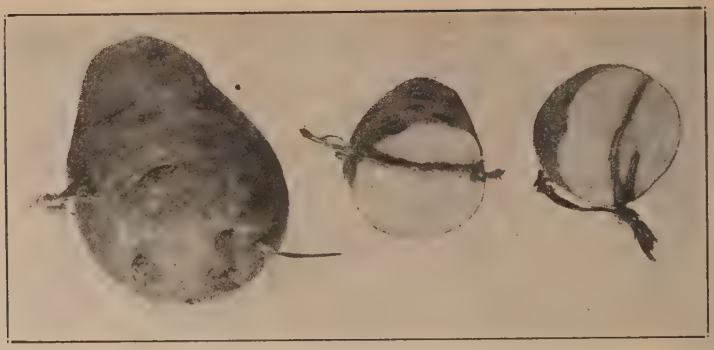

Fig. 21. Quack Grass Injury

Fig. 22. Witches' Broom

Quack Grass Injury

The underground rootstalks of quack grass may grow through potato tubers, as shown in Figure 21. This condition is, however, more of a curiosity than a disease. Affected tubers should not be planted.

"Witches' Broom"

Occasionally potato plants produce many small sprouts with small leaves, as illustrated in Figure 22. This occurs rarely and may be

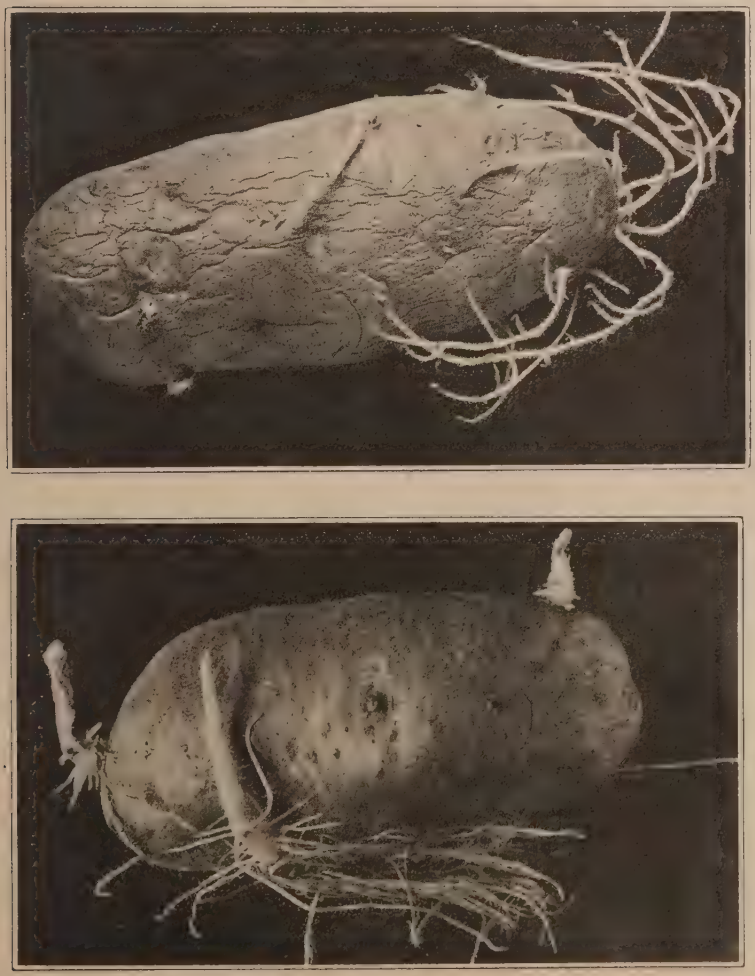

Fig. 23. Above, Spindling Sprout; below, Normal Sprout of Burbank

similar to spindling sprout. Selection of vigorous seed will prevent this trouble.

Spindling Sprout

Spindling sprout, as shown in Figure 23, is a condition in which the sprouts are very narrow and weak. This disease is not caused by a parasite, but represents a loss in vigor of the sprouts. It is not commonly found in Minnesota, and can be avoided by using vigorous seed which has been stored properly.

"No Tops"

Occasionally when the potatoes have been subjected to unfavorable conditions, the sprouts produced the succeeding year, instead of growing up through the ground, may produce small secondary tubers, as illustrated in Figure 24. This trouble was quite common in 1917, probably because the seed tubers had been produced during hot weather in 1916. The only way to prevent this trouble is to use good vigorous seed tubers.

Fig. 24. "No Tops"

"Running-out" or Lack of Vigor

While much of the so-called "running out" of potatoes is brought about by such diseases as mosaic and leaf roll, a loss of vigor may result when potatoes are grown under unfavorable conditions. This is illustrated by the well-known fact that southern growers obtain poor results when they use seed potatoes produced in the south. Under certain soil conditions in Minnesota, the yield of potatoes may continue to decrease year after year until it no longer pays to plant the strain of potatoes being used. Under such circumstances the grower should obtain a new strain, or he may even find that it will pay to get new seed every year. Usually in Minnesota, however, the use of seed plot methods as described later, will suffice to keep up the vigor of the stock.

METHODS OF PREVENTION AND CONTROL

Methods of prevention have been described briefly for the diseases mentioned in the preceding pages. Certain control measures may apply to a number of diseases. General control measures are here discussed, considering in particular good farming practices which decrease the amount of disease and increase the vigor and yield of the crop.

SEED SELECTION

Seed selection is one of the most important factors in producing first-class potatoes. The control of such diseases as Fusarium wilt, black leg, mosaic, leaf roll, and late blight, which are carried over inside the seed and can not be eliminated by disinfection, depends mostly on using healthy tubers (12).

Some success may be obtained by careful bin selection, altho a better method is to select the potatoes at digging time. However, to get the best results diseased plants should be removed from the field in which the seed stock is to be selected. Every grower should maintain each year a special seed plot large enough to supply sufficient seed potatoes for the succeeding year. A plot of about one-tenth the total acreage is large enough. Certain practices are essential to success.

In the first place good, vigorous seed stock of the variety best suited to local conditions is necessary. Stock that produces a large percentage of weak or degenerate hills will not give good results. Such a strain should be disposed of and seed of known satisfactory performance should be secured. *Use certified seed.*

Before planting, treat the potatoes with corrosive sublimate, as discussed under seed treatment.

Good growing conditions are essential for the production of vigorous seed. Therefore the most suitable piece of ground on the farm should be selected for the seed plot.

Thoro deep cultivation while the plants are young, followed by shallow cultivation later in the season is necessary for the development of a vigorous root system and it also conserves moisture. The number of cultivations will, of course, depend on the seasonal conditions. A properly kept seedbed aids greatly in the production of good seed stock.

A thoro inspection of the seed plot should be made about blossoming time and all undesirable plants should be removed. At this time varietal mixtures are most readily detected. Such diseases as blackleg, Rhizoctonia, mosaic, and leaf roll are usually conspicuous at this time and all affected plants should be removed. Later inspections should be made for wilt and also for the diseases mentioned, which may have developed since the first inspection. Tubers produced under diseased and unthrifty vines should be removed so that only vigorous stock remains at digging time.

Spray thoroly in order to control insect pests and such diseases as early and late blight. See discussion of spraying.

The seed plot should be harvested separately from the rest of the field and the tubers should be kept in different bins from those used for storing the main crop. It is best to dig first by hand enough seed potatoes for the following year's seed plot, from the best yielding and most uniform hills. Then the rest of the plot can be harvested for planting the main crop the next year.

All seed stock should be handled carefully to avoid unnecessary bruising or other injury. It is best to put the potatoes to be used in the seed plot in slatted crates as soon as they are dug, and then place them in storage as soon as possible. A clean, well ventilated storage cellar, in which the temperature is between 35 and 40 degrees F., will keep seed potatoes in excellent condition until planting time the next spring.

DO SEED PLOT METHODS PAY?

In 1914 the Section of Fruit and Vegetable Investigations, the Division of Agricultural Extension, the Section of Plant Pathology, and the county agent of Clay County, coöperated with several Clay County farmers in experiments to determine the value of seed selection and seed disinfection. Since then supervised seed plot demonstrations have been continued in Clay County and introduced into practically every potato-growing county in the state. As a result of these demonstrations many growers now practice seed-plot methods.

The tables show the results obtained on the supervised plots in Clay County in 1919 and a summary of the plot work in Clay County from 1914 to 1919 inclusive:

TABLE I

RESULTS OF SEED POTATO SELECTION AND DISEASE CONTROL DEMONSTRATIONS IN CLAY COUNTY, 1919

Grower	Yield per acre		Difference in yield per acre in favor of plot	Percentage of diseased vines	
	Seed plot	Field		Seed plot	Field
	Bushels	Bushels	Bushels		
U. Legler	125	115	10	1.75	4.75
Wm. Sprung	110	75	35	1.25	2.75
Theo. Skrei	195	175	20	1.50	2.10
O. Syvertson	125	100	25	2.20	6.50
T. U. Wiger	125	110	15	1.00	3.00
E. J. Corwin	135	105	30	0.00	0.50
J. F. Prenosill	170	142	28	2.00	5.50
Average	140.7	117.4	23.3	1.38	3.59

TABLE II

SUMMARY OF RESULTS OF POTATO SEED PLOT DEMONSTRATIONS IN CLAY COUNTY FROM 1914 TO 1919, INCLUSIVE

Year	Number of plots	Average yield per acre in seed plots	Average yield per acre in fields	Difference in yield per acre in favor of plot	Quality of plots	Quality of fields
		Bushels	Bushels	Bushels		
1914	4	228.0	128.0	100.0	Practically no disease.	
1915	10	130.0	86.0	44.0	0.9 per cent disease. Better type, greater uniformity.	3.6 per cent disease.
1916	12	187.2	154.2	33.0	Trace of disease	1.5 per cent disease.
1917	6	101.0	77.5	23.5		
1918	9	147.1	93.9	53.2	0.86 per cent disease. Better uniformity and type.	5.7 per cent disease.
1919	7	140.7	117.4	23.3	1.38 per cent disease	3.62 per cent disease.
Av.	8	155.7	109.5	46.2		

These results are representative of results secured in other counties also. The proceedure in conducting these plots has been to select uniform potatoes true to type, and to cut off the stem end of all tubers, especially if there was a considerable amount of wilt or blackleg in the field in which the potatoes were produced. The tubers were then treated with corrosive sublimate, and planted in the regular potato field, either at one side or in the most favorable part of the field. Field

inspections were made at blossoming time and about a month later, and all undesirable plants were removed. All foreign varieties were removed at the first inspection. Comparisons of yield and type were obtained at digging time. Practically all the seed plots yielded more per acre than the regular field. The plots also produced more uniform and healthier potatoes.

Fig. 25. Treating Seed Tubers. (Cut furnished by Verne Steward, Princeton.)

Every potato grower should pay more attention to seed selection and disinfection. The use of a seed plot should become a part of the general farm practice.

HANDLING AND DISINFECTING SEED

Potatoes that are to be used for seed should be handled carefully. They should be disinfected at some time before cutting, unless they are free from scab, black scurf, and other surface diseases and have been kept in clean bins.

SEED TREATMENT

Materials used: Corrosive sublimate (POISON) is the most commonly used disinfectant for seed tubers. Ordinary formaldehyde solution kills the scab organism, but is not so effective as corrosive sublimate against the black scurf. Hot formaldehyde has been found to kill black scurf, but the temperature must be kept at the right point. Corrosive sublimate is somewhat more expensive than formaldehyde, but is worth more if black scurf is present on the tubers. Other substances also are being tried.

To make corrosive sublimate solution, use 4 ounces of the sublimate (mercuric bichloride) to each 30 gallons of water. Dissolve the corrosive sublimate in from 2 to 4 gallons of hot water, then add enough water to make a total of about 30 gallons. Make smaller or larger quantities in the same proportion; for example, use 1 ounce of sublimate to 7½ gallons of water or ½ ounce to a little less than 4 gallons of water.

Make the formaldehyde solution by mixing one pint (one pound) of 40 per cent formaldehyde with 30 gallons of water, or at the rate of 1 ounce of formaldehyde to about 2 gallons of water, for small quantities of potatoes.

Fig. 26. Effect of Treatment on Crop Produced

Seed affected with black scurf. No. 1, seed treated with corrosive sublimate solution: rear, clean, front, black scurf, 4.0 per cent of progeny affected. No. 2, untreated: rear, clean, front, black scurf, 39.6 per cent of progeny affected. Results in 1919.

METHODS OF DISINFECTION

It is safer to treat the potatoes before cutting, altho if the seed pieces are dried thoroly and quickly after treating, they may be treated after cutting.

Barrels may be used unless large acreages are planted, when it may be convenient to make special wooden vats for treating. Use several fifty-gallon barrels. Bore holes near the bottom and make wooden plugs to fit. The barrels may conveniently be set on a platform about two feet from the ground or floor, so that pails can be set under them to transfer the solution. Put about 30 gallons of solution in half the barrels, and add the potatoes. If corrosive sublimate is used, allow the first lot of potatoes to soak 1½ hours (unless the tubers

are sprouted, in which case the time should be shortened, as mentioned below). The second time the solution is used, soak about 1¾ hours; and the third and fourth times used, treat for 2 hours, and then discard the solution and make a fresh lot. If the potatoes are clean, the solution may be used longer if one ounce of corrosive sublimate dissolved in water is added for each 30 gallons after each treatment. While one lot of potatoes is soaking, other lots may be put in the empty barrels, and the solution drawn off at the proper time and poured over these potatoes. The treated potatoes should be spread out in a clean place to dry, or may be cut at once, then allowed to dry quickly.

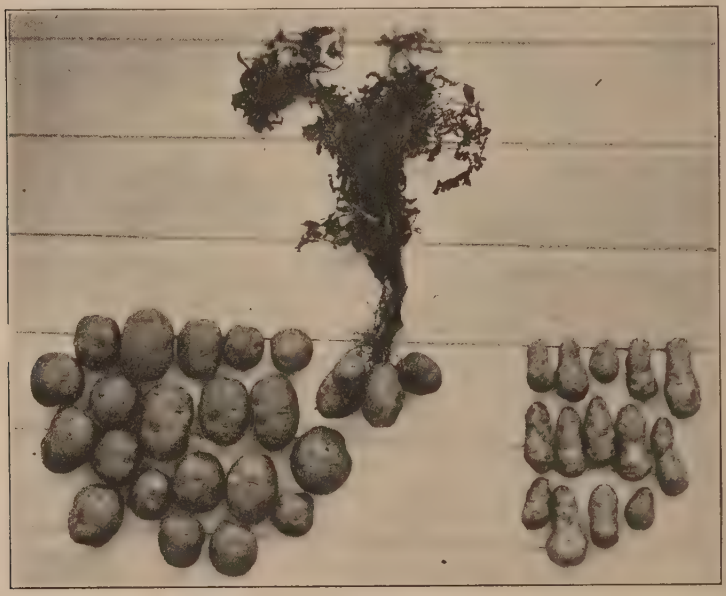

Fig. 27. Effect of Selection

Precautions—Corrosive sublimate is a deadly poison to man or animals when taken internally, but at the dilution used will not cause injury externally beyond a slight roughening of the skin. The hands should not, however, be kept moistened with the solution for any extended length of time. Formaldehyde is less poisonous than corrosive sublimate. Metal containers will be corroded by corrosive sublimate, but not by formaldehyde. It is very important that potatoes with sprouts half an inch long or longer be treated for a shorter time, about half an hour, and handled carefully so as to break off as few sprouts as possible. Use only clean bins and containers after treatment.

If seed potatoes are free from disease and have been kept in clean bins, it is not necessary to treat them.

Results at University Farm.—Seed treatment experiments have been performed for several years at University Farm. The prevention of black scurf has been considered particularly, since scab does not ordinarily occur in the soil at the station.

TABLE III

VALUE OF DIFFERENT SEED TREATMENTS FOR BLACK SCURF
AVERAGE FOR FIVE YEARS

Treatment	Strength	Time of soaking	Percentage of crop free from black scurf
		Hours	
Corrosive sublimate	4 ounces to 30 gal. water	2	65.2
Copper sulphate	3 pounds to 50 gal. water	2	64.7
Formaldehyde solution	1 pint to 30 gal. water	2	56.3
No treatment			32.5

Corrosive sublimate has given the best results altho copper sulphate (blue vitrol) is almost equally effective. Blue vitrol is not yet recommended because it may injure the seed.

Clean tubers give the best results. In 1918, clean tubers were selected and planted without treatment. An average of 22 plots gave 7.2 per cent of black scurf on the progeny, in contrast to the best results from treatment of diseased tubers, in which 15.5 per cent of the crop had black scurf.

Experiments have shown that sulphur dusted over the seed and lime-sulphur diluted to 1 to 30 or 1 to 40 are not effective in killing black scurf on tubers. Shorter treatment, half an hour, has not been found as effective as the regular one and a half- or two-hour treatment.

Disinfecting bins.—Bins, sacks, barrels, or other containers should be disinfected before treated or cut potatoes are put into them. Bins also should be disinfected thoroly before potatoes are put into them in the fall. For disinfecting bins and all containers or tools, use a mixture of 1 pint of formaldehyde to from 5 to 10 gallons of water. Blue vitrol, 1 pound to 10 gallons of water, may also be used for bins, but not for metal containers or tools.

Sun-sprouting seed.—For small plots or gardens, it is an excellent practice to place the seed tubers in a thin layer where the sun and light will strike them for two or three weeks before planting. This allows the development of sturdy green sprouts. Care should be taken here as always not to break these off in planting. Tubers with weak sprouts should be discarded. Sun sprouting can hardly be practiced when a planter is used.

Cutting seed (13).—Tubers should be cut carefully. In general it is better to cut by hand, since undesirable and diseased tubers can be discarded. It is advisable to keep one knife in a formaldehyde solution until a diseased tuber is cut into with the other, then change knives. Keep cut seed in clean bins and containers, and spread out in a thin layer so that it will dry quickly. If necessary, shovel it over to facilitate drying. With careful handling seed may be kept from one to three weeks after cutting. When rots start on the seed pieces, a very poor stand is likely to result, so that the cut seed should be allowed to dry thoroly and quickly, in order to form a corky coating over the cut surface.

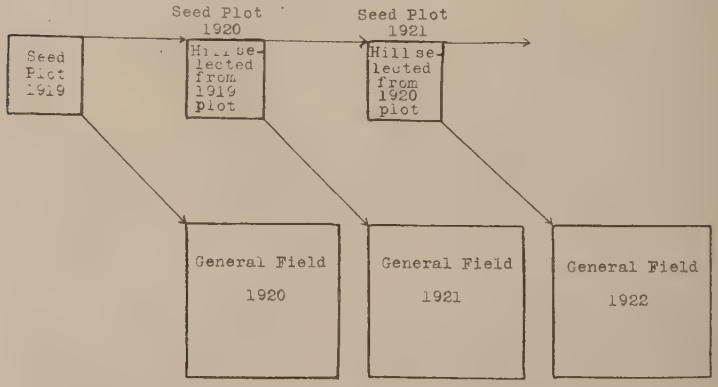

Fig. 28. Diagram of Seed Plot

SOIL MANAGEMENT AND CULTURAL PRACTICES

Some of our worst diseases may live in the soil for years. Hence it is important that carefully selected and disinfected seed should be planted on good, clean soil. Altho a well-drained sandy loam is considered the best soil for potatoes, the most desirable type of soil may depend on the varieties to be grown. Certain varieties may do well on light sandy soils, while other varieties may do better on heavier clay soils.

Such diseases as scab, powdery scab, Rhizoctonia, and Fusarium wilt persist in the soil, and if potatoes are grown successively for several years or every other year on the same soil, these diseases will accumulate and diseased crops will be produced. A rotation in which potatoes are grown once every four or five years on the same piece of ground will do much toward keeping the damage done by these diseases down to a minimum. The rotation in which potatoes follow a cover crop, such as clover or alfalfa, is the best. The plowing under of such

a crop enriches the soil, improves its tilth, and adds a slight acidity which decreases scab.

The rotation plots at University Farm have shown an accumulation of fungi in the soil when potatoes are grown every year. In 1918, the tubers produced on a plot of ground that had grown potatoes each year for 4 years had 20.8 per cent of black scurf; after a three-year rotation only 3.3 per cent of black scurf occurred on the progeny.

The reaction of the soil exerts some influence on the development of scab. The addition of lime, wood ashes, or fresh manure makes the soil more alkaline and increases the danger of producing a scabby crop.

Deep plowing gives the best results, since potatoes require plenty of loose soil.

The time of planting depends upon conditions. Unless it is desired to harvest the potatoes for the early market, it is better to wait until the ground has warmed up enough to insure prompt sprouting. For small plots, sun-sprouted seed gives good results on account of the rapidity with which the sprouts grow.

Cultivation should be clean, so as to kill weeds and allow the potato plants to develop vigorously. The absence of weeds allows better air circulation and lessens the danger from blights on the leaves.

ROGUING

Roguing ("removing the rogues") is practiced to eliminate plants of another variety that may be accidentally present, and to remove and destroy plants and their tubers which are weak or show symptoms of mosaic, leaf roll, blackleg, or wilt. Roguing is described under seed selection. Seed plots and fields intended for seed purposes should be rogued.

Roguing can best be done at flowering time, when mixtures of varieties can easily be detected. The vines and tubers produced by these mixtures or by diseased plants should be carried to the end of the row. A second roguing should be made about a month after flowering time, in order to remove plants which show disease at that time. The removal of plants and tubers affected with blackleg may save considerable loss from rotting in storage.

SPRAYING

The presence of insects usually makes it necessary to use a poison in the spring. For methods of control of the "potato bug" (Colorado potato beetle) and other insects, obtain Circular 47 of the State

Entomologist, Special bulletin 29, of the Agricultural Extension Division, or Minnesota Farmers' Institute Annual for 1919.[1] For the prevention of late blight and early blight, and for keeping off leaf-hoppers so that hopperburn (tipburn) will not be so serious, bordeaux mixture should be used.

Bordeaux mixture is made from 5 pounds of copper sulphate (bluestone), 5 pounds of stone lime (quicklime), and 50 gallons of water. Dissolve the bluestone in 25 gallons of water by hanging the crystals in a sack at the top of the water, slack the lime in a little water and add water to make 25 gallons, then pour the two together into the sprayer and use at once. For spraying on a larger scale, use stock solutions. Dissolve bluestone in a wooden container at the rate of 1 pound to each gallon of water. In another container slake the lime and add enough water so that there is one pound of lime to each gallon of water. Then fill the sprayer one-third full of water, add the required amount of stock solution of lime (stir first) through a strainer (5 gallons of solution, equaling 5 pounds of lime, for a 50-gallon sprayer), fill the sprayer two-thirds full, add the stock solution of bluestone in the same amount as the lime solution, and fill the sprayer with water. Other methods may be devised. Poison for insects may be added to the bordeaux mixture.

Spray first when the plants are from 8 to 12 inches high, and repeat about every two weeks, applying 3 or 4 successive sprays unless late blight threatens, in which case spray oftener. Thoro spraying is an insurance that more than pays for itself, and is an important method of increasing the yield.

HANDLING, STORING, AND SHIPPING

Careless handling of potatoes after digging results in serious loss from rots. This loss will continue as long as potatoes are handled like coal. Every bruise or injury on a potato makes it easy for various storage rots to develop. These rots have their origin in the soil or in unclean bins and it is important that great care be exercised while digging and while handling the potatoes after placing them in storage. It might be well to keep badly bruised potatoes out of the storage cellar, since a large number of tubers so injured are certain to rot and to spread the rot throughout the bins. The ideal method of handling potatoes is to place them in crates which, when filled, are hauled to the storage cellar and carefully dumped wherever wanted.

If it is necessary to drop the potatoes several feet much damage can be avoided by providing a chute for dropping them into the cellar.

[1] When asking for Farmers' Institute Annual, enclose stamps to cover parcels post rate from your post-office to St. Paul.

Storage cellars should be thoroly disinfected before potatoes are put into them. A strong solution of bluestone, 1 pound dissolved in 10 gallons of water, or formaldehyde, 1 pint in 10 gallons of water, should be used to wash or spray the bins.

Storage rots spread most rapidly when the temperature is high and the ventilation poor. In order to prevent serious loss the temperature should be kept at from 35 to 40 degrees F., and the cellar should be kept as dry as possible.

Potatoes also should be handled carefully when they are being taken out of the cellar and prepared for shipment. Whether the potatoes are graded on the farm or at the loading point, it is good policy to remove all tubers showing any rot whatever. Simply running them over a grader does not remove rotted or bruised potatoes. Proper heating and ventilation of cars are also important factors in preventing rots in shipment. A little attention to these details will often prevent serious consequences when the potatoes arrive at their destination (14, 15).

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The University of Minnesota

AGRICULTURAL EXPERIMENT STATION

THE USE OF BORDEAUX MIXTURE FOR SPRAYING POTATOES

BY

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IN CHARGE OF POTATO SEED CERTIFICATION

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SUMMARY

Bordeaux mixture is a preventive of late blight of potatoes. It also reduces the injury from other leaf diseases, and repels certain insects. It is an insurance against the serious loss that late blight may cause, but pays for itself if late blight is absent.

Spraying experiments were begun in 1888, at University Farm. Results are available covering experiments performed during sixteen years. These tests were carried out in 1888, 1893, 1894, 1895 and each season for the last twelve years.

The average increase in yield from spraying, at University Farm, in the absence of late blight, has been more than thirty bushels per acre for late varieties and about twenty-seven bushels for early varieties.

A 5-5-50 mixture has been found to be better than weaker mixtures, at University Farm.

Preliminary results indicate that spraying may result in the production of more vigorous tubers, as shown by their performance when planted the succeeding year.

No definite correlation was found between the weather and the yield from sprayed plots, except that extremely dry weather or early frosts cut down the increase. In wet and cool seasons the danger from late blight is greater than in dry seasons.

Good results are reported from the substations, particularly from Crookston.

Coöperative tests and the experience of growers indicate that spraying increases yield under farm conditions in various parts of the state.

Home-made bordeaux mixture is the best application, for large acreages at least. Certain ready-made mixtures are quite effective. The cost of making and applying bordeaux mixture is comparatively small.

The results from spraying in Minnesota agree with those obtained in other states.

THE USE OF BORDEAUX MIXTURE FOR SPRAYING POTATOES

By G. R. Bisby and A. G. Tolaas

INTRODUCTION

Bordeaux mixture is applied to potato plants particularly to prevent late blight, one of the most serious of potato diseases. Bordeaux mixture is also effective in lessening early blight and tipburn. Since an epidemic of late blight occurs in Minnesota only in seasons in which the weather is moist and cool, it has been a question in the minds of many as to whether it would pay to spray with bordeaux every year. In other words, will spraying give an increase in yield when late blight is absent as well as when it is present? The value of bordeaux mixture as a preventive of late blight has been abundantly proved. The value of this spray in regions where late blight occurs infrequently or is entirely absent must be determined by experiments performed in the various localities. All data submitted in this bulletin were obtained in the absence of late blight.

Potato spraying experiments were begun in Minnesota thirty-two years ago by the late Professor S. B. Green. For the sake of completeness, and as some of the older results are rather inaccessible, a brief review will be included of certain published work in addition to the unpublished results obtained during the last ten years. The writers are indebted to A. R. Kohler and Richard Wellington, formerly of the Division of Horticulture, for the use of certain unpublished data relative to spraying, and for suggestions; also to Dr. E. M. Freeman, who initiated the experimental spraying in the Division of Plant Pathology, and to Dr. E. C. Stakman for supervision of this work for several years.

One of the first published reports indicating the occurrence of potato diseases in Minnesota bears the date 1883(1). While this paper did not deal with potato diseases as found in this state, the discussion by members of the Horticultural Society suggests that losses had already been experienced here from certain of the diseases. It was about this time that Millardet, in France, was making experiments with copper compounds as preventives of the downy mildew of the grape. Lodeman (2) has given a history of the use of spray materials and of the development of bordeaux mixture. He (p. 29) considers that Jouet, following the suggestion of Prillieux, first sprayed potatoes with a copper sulfate-lime mixture for the prevention of late blight in 1886. Formulas for copper sulfate-lime mixtures were published in the United States also about 1886.

EXPERIMENTS AT UNIVERSITY FARM

One of the first states to carry on spraying experiments with a copper sulphate-lime mixture was Minnesota. The report published in 1889 (3, see also 28) by S. B. Green, covers experiments performed in 1888. This work has been overlooked by Lodeman and others in considering the history of the use of fungicides in the United States. The following summarizes the results Professor Green obtained from spraying:

The variety used in 1888 was Polaris (an early variety), planted in rows 100 feet long, and each row was sprayed with a different compound to kill the Colorado beetle and to arrest or prevent "blight and other diseases of the foliage." Among the preparations used was "Gironde or bordeaux mixture" made from 32 pounds of copper sulphate dissolved in 58 gallons of water, into which was poured a mixture of 60 pounds of lime slaked in 15 gallons of water. This thick mixture was applied to one row with a small broom, and Green noted that this mixture resulted in the production of a dark, healthy color by the leaves. From the 100-foot row sprayed with this bordeaux mixture, he obtained a yield of 186 pounds, which is at the rate of 449 bushels per acre; from the use of paris green, 143 pounds, or a rate of 345 bushels per acre.

This result with bordeaux mixture was significant. Professor Green evidently did not, however, have an opportunity to continue similar experiments until 1893, since he mentioned (4) that his experiment that year was the second at the Minnesota station. The work in 1893 was carried on in coöperation with a grower adjoining University Farm. Four rows in a field of Burbank potatoes were sprayed with a 6:4:44 bordeaux mixture. In spite of the fact that "little or no blight" was present, and that all vines grew until killed by frost, the sprayed rows produced 10½ bushels of merchantable potatoes, and adjoining unsprayed rows yielded only 8 bushels. This was equivalent to 210 and 160 bushels per acre respectively. The tubers were found to be larger under sprayed vines.

It was recommended that bordeaux mixture be made a few days before using. Three sprayings were said to be generally sufficient, tho at least 4 were recommended if the season was wet or blight threatened. Green considered that spraying should be begun when the plants were about half grown.

In the discussion of a paper (5) "Late Blight and Rot of the Potato" before the Horticultural Society, Professor Green mentioned (probably from memory) what were apparently the same results, altho the figures given there differ slightly. He suggested spraying

first when the tops are eight inches high, about the middle of July, then again about the 1st and the 20th of August.

The present-day formulas for bordeaux mixture had not yet come into general use. However, Green recommended 100 gallons per acre as the proper quantity to apply for the first application and 150 gallons for each of the two later ones, and figured the cost of the spray at about one cent per gallon (copper sulphate at 6 or 7 cents a pound, lime at 1-3 cent per pound). A force pump and spray nozzle were recommended for larger areas.

The increase in yield in 1893 on the plots sprayed with bordeaux and evidently also in 1888, occurred in the absence of an epidemic of late blight.

In 1894 less favorable results with bordeaux mixture were secured. Professor Green stated (6): "This season the treatment gave but very slight returns, and although it increased the yield, it was such a small increase that it did not pay for the labor involved in the application of the poisoned solution." He attributed the small returns to seed treatment with corrosive sublimate, to the use of new land, and to an excessively dry season. A 5-5-50 formula was recommended.

In 1895 Green found (7) in some cases a decrease in yield on the sprayed plots. He observed that in 1894 and 1895 "the loss from potato blight in this state has been almost nothing." Table I gives the results obtained in 1895 from the application of a 5-5-50 bordeaux mixture.

TABLE I

SUMMARY OF RESULTS OF SPRAYING AT UNIVERSITY FARM IN 1895

Variety	Times sprayed	Total yield per acre	Remarks
		Bushels	
Burbank	4	216.5	Average 2 plots
Burbank	3	229.5	Average 2 plots
Burbank	2	197.0	Average 2 plots
Burbank	1	213.5	Average 2 plots
Burbank	*	268.3	Average 3 plots
Irish Daisy	2	323.0	
Irish Daisy	*	316.0	
Acme	2	151.0	
Acme	*	155.0	
Rural New Yorker	4	285.0	
Rural New Yorker	3	276.0	
Rural New Yorker	2	297.0	
Rural New Yorker	1	293.0	
Rural New Yorker	*	276.0	
Early Ohio	3	212.0	
Early Ohio	2	217.5	Average 2 plots
Early Ohio	*	217.0	

* Not sprayed.

Professor Green recognized the value of spraying with bordeaux mixture if the danger from late blight increased, but was "extremely doubtful if it will pay to use these preventions under the present circumstances." It is not now clear why the sprayed plots yielded less than the unsprayed in several cases that year. At any rate he evidently decided that other problems were more immediately pressing, and did not try further experiments with fungicides as sprays, altho he was strongly in favor of disinfecting the seed. In 1898 (8) and 1901 (9) he mentioned bordeaux, without adding any further experimental data.

A. R. Kohler took charge of experimental work on potatoes for the Division of Horticulture in 1907, and in 1909 published a bulletin (10) including spraying results secured in 1908. He used the Sir Walter Raleigh variety of potatoes, in test plots of four rows about 3 feet apart and 132 feet long, and a 5-5-50 bordeaux mixture was applied at the rate of 65 gallons per acre each application. Table II summarizes his results (Table VIII, p. 329-330, Bulletin 114).

TABLE II

RESULTS FROM SPRAYING POTATOES WITH BORDEAUX MIXTURE, 1908

Spray	Yield per acre		
	Marketable	Small	Total
	Bu.	Bu.	Bu.
Not sprayed	114	12.5	126.5
Sprayed every 7 days, 6 times, beginning July 23	131.6	12.1	143.7
Corresponding check plot	112.9	11.6	124.5
Sprayed every 10½ days, 4 times, beginning July 23	127.5	10.7	138.2
Corresponding check plot	111.7	10.8	122.5
Not sprayed	110.6	9.9	120.5
Sprayed every 14 days, 3 times, beginning July 23	122.4	11.3	133.7
Corresponding check plot	114.0	10.6	124.6
Sprayed every 21 days, July 23 and August 23	116.6	11.3	127.9
Corresponding check plot	117.3	11.3	128.6
Not sprayed	120.7	12.0	132.7

Kohler submitted figures indicating that a profit would result from spraying 3, 4, or 6 times but not from two sprayings. The foliage of the sprayed plots was healthier throughout the growing season than that of the unsprayed plots.

Spraying experiments were continued in 1909 by Mr. Kohler. The results published (11) by him are summarized in Table III. A 5-5-50 bordeaux mixture was applied with a compressed air sprayer at the rate of 50 gallons per acre (with two exceptions in which 25 gallons per acre were applied the first time only). The plots were of 4 rows 3 feet apart and 73 feet long.

TABLE III

RESULTS FROM SPRAYING POTATOES WITH BORDEAUX MIXTURE, 1909

How Sprayed	Marketable yield per acre Bushels
I. Sir Walter Raleigh	
Weekly, 6 times, beginning July 13	192.1
Every 10½ days, 4 times, beginning July 13	187.5
Every 14 days, 3 times, beginning July 13	202.3
Every 17½ days, 3 times, beginning July 13	162.0
Every 10½ days, 6 times, beginning June 23	185.3
June 23, July 7, 15, 30, Aug. 13	166.0
Check, average 10 plots	166.1
II. Early Ohio	
Weekly, 4 times, beginning July 13	195.6
Every 10½ days, 3 times, beginning July 13	186.0
Every 14 days, 2 times, July 13, 27	223.2
Every 17½ days, 2 times, July 13, 30	226.0
June 23, July 8, 15, 27	219.0
June 23, July 8, 15, 30	226.7
Check, average 9 plots	218.9

Kohler found that the foliage of the sprayed plants remained in better condition than that of the unsprayed plants on the Sir Walter Raleigh variety in 1909, as had been the case in 1908. He placed the average gain in the condition of foliage during the season of 1909 on this late variety of potatoes at 8.3 per cent, and the average increase in yield at 16.8 bushels per acre, or 10.1 per cent. For 1908 the average yield had been increased 10.6 bushels, or 9.1 per cent, and the condition of foliage was 7.2 per cent better. In both years spraying paid financially, altho no late blight appeared either year. The results from spraying the Early Ohio variety were inconclusive since little or no increase followed the application of bordeaux mixture.

During 1910 and 1911 Kohler continued spraying experiments. Abstracts are presented from his unpublished results through the courtesy of the Division of Horticulture. Thanks are due Mr. Kohler for the use of these data.

In 1910 Kohler again used 5-5-50 bordeaux mixture applied by hand with a Brandt compressed air sprayer. The plots were each of 4 rows, 4 rods long.

In the experiments carried out in 1911 for the Division of Horticulture by Mr. Kohler, plots each of 4 rows, 4 rods long were sprayed with 5-5-50 bordeaux mixture applied by hand with a Simplex compressed air sprayer. The check plots for Early Ohio and Sir Walter Raleigh consisted of 6 rows, 4 rods long.

TABLE IV

RESULTS FROM SPRAYING POTATOES WITH BORDEAUX MIXTURE, 1910

Division of Horticulture

Spray used	Marketable yield per acre Bushels
I. Sir Walter Raleigh	
Sprayed weekly, 11 times beginning June 28, 25 gal. per acre first time, 50 gal. second, 75 gal. other times	189.0
Sprayed weekly as before, 50 gal. per acre first time, 75 gal. second, 100 gal. other times	187.8
Sprayed every 10½ days, 8 times, beginning June 28, amounts as in preceding	184.9
Sprayed as preceding except 50 gal. per acre first time, 75 gal. succeeding times	190.1
Sprayed as preceding except 25 gal. per acre first time, 50 gal. succeeding times	198.1
Sprayed bi-weekly 6 times beginning June 28; 25 gal. per acre first time, 75 gal. other times	183.5
Sprayed weekly, 8 times beginning July 19; 50 gal. per acre first time, 62½ second, 75 gal. other times	193.4
Sprayed July 19, 29; Aug. 9, 19, 30; Sept. 9; 50 gal. per acre first time, 75 gal. other times	197.5
Sprayed as preceding except 37½ gal. per acre first time, 50 gal. other times	180.9
Sprayed July 19; Aug. 2, 16, 30; Sept. 13; 50 gal. per acre first time, 75 gal. other times	194.5
Not sprayed, average 16 plots	159.5
II. Early Ohio	
Sprayed July 19, 26; Aug. 2, 9, 16, 23; 75 gal. per acre each time	121.0
Sprayed as above except 100 gal. per acre each time	123.3
Sprayed July 19, 29; Aug. 9, 19; 100 gal. per acre each time	130.0
Sprayed July 12, 22; Aug. 2, 12, 23; 75 gal. per acre first time, 100 gal. other times	125.1
Sprayed July 19, 29; Aug. 9, 19; 75 gal. per acre each time	144.0
Sprayed July 12, 22; Aug. 2, 12, 23; 50 gal. per acre first time, 75 second, 100 gal. last 3 times	133.2
Not sprayed average 4 plots	91.0

TABLE V

RESULTS FROM SPRAYING POTATOES WITH BORDEAUX MIXTURE, 1911

Division of Horticulture

Spray used	Marketable yield per acre Bushels
I. Sir Walter Raleigh	
Sprayed July 19, 28; Aug. 8, 18, 29; 50 gal per acre each time	266.9
Sprayed as above, except 75 gal. per acre	253.8
Sprayed as above except 100 gal. per acre	270.1
Sprayed July 19, 25; Aug. 1, 8, 15, 22, 29; Sept. 7; 50 gal. per acre each time	236.0
Sprayed as above except 75 gal. per acre	280.2
Sprayed July 19; Aug. 1, 15, 29; 50 gal. per acre	241.2
Sprayed as above except 75 gal. per acre	224.1
Sprayed June 27; July 8, 19, 28; Aug. 8, 18, 29; 25 gal. per acre first 2 times, 37½ gal. third time, 50 gal. last 4 times	243.0
Sprayed as above except 25 gal. per acre first time, 37½ gal. second, 50 gal. third, 75 gal. last 4 times	274.5
Sprayed June 27; July 7, 19, 25; Aug. 4, 15, 25; 25 gal. per acre first time, 50 gal. next 2 times, 75 gal. last 4 times	287.1
Sprayed July 19, 25; Aug. 4, 15, 25; 50 gal. per acre first time, 75 gal. other times	276.1
Not sprayed, average 4 plots	192.7
II. Early Ohio	
Sprayed July 11, 21; Aug. 1; 50 gal. per acre	132.6
Sprayed as above except 75 gal. per acre	140.8
Sprayed June 20, 30; July 11, 21; Aug. 1; 25 gal. per acre first 2 times, 50 gal. last 3 times	162.5
Sprayed as above except 25 gal. per acre first time, 37½ gal. second time, 75 gal. last 3 times	174.8
Not sprayed, average 2 plots	134.9
III. Early Harvest	
Not sprayed	180.3
Sprayed July 11, 21; Aug. 1, 11, 22; 75 gal. per acre each time	233.1
IV. Norcross	
Not sprayed	184.6
Sprayed July 11, 21; Aug. 1, 11, 22; 75 gal. per acre each time	226.3

These results secured by Kohler during four years in which late blight did not occur indicate that considerable increase in yield may be expected at University Farm from the application of bordeaux mixture. In 1910 Kohler stated in his notes that "the weather was hot and dry during much of the growing period of the Early Ohio variety, with the result that there was considerable injury to the foliage from tipburning. Much of the benefit from the bordeaux mixture on the Early Ohio in that year must have been due to a lessening of the amount of tipburn on account of the protection it afforded the leaves against the sun's rays." The weather was again hot and dry during the early part of 1911, and spraying paid on the Early Ohio when begun early.

The yield in different plots of potatoes varied considerably and the results secured by Kohler were not absolutely consistent in certain minor respects, but nevertheless they give valuable information as to the effect of spraying. Considerable increase in yield resulted from spraying the late variety. Kohler concluded that spraying late potatoes should begin at University Farm about the middle of July and should be repeated at intervals of ten or eleven days. He recommended the application of 75 gallons per acre, and that spraying might be discontinued when 15 or 20 per cent of the foliage was dead. In the presence of late blight, later and thoro applications of bordeaux would of course be advisable.

Kohler sprayed also with lime-sulfur in 1911. He used a 1:32 and a 1:40 dilution. While favorable results were obtained, further trials at Minnesota and other stations indicate that lime-sulfur is not so valuable as bordeaux mixture as a spray for potatoes.

The comparative yields of the sprayed and unsprayed plots mentioned are summarized later.

The Division of Plant Pathology and Botany undertook experiments, beginning in 1909, to determine further the effect of using bordeaux mixture on potatoes. It was considered important to determine whether spraying each year paid, and to obtain data on the effect on the various diseases. This work has been continued to the present. The results are summarized in Table VI.

TABLE VI

RESULTS OF SPRAYING POTATOES

(Section of Plant Pathology)

Year	Variety	Spray used	Dates of spraying	Total yield		Notes
				Per plot	Rate per acre	
				Pounds	Bushels	
1910	Early Ohio	Check, no fungicide		57.5	153.3	Plants died early.
	Burbank	Do		31.0	82.7	Tubers few and small.
	Early Ohio	5–5–50*	July 2, 11, 23, 29; Aug. 5	109.0	290.7	Plants remained green long.
	Burbank	Do	Do	140.0	373.3	Plants vigorous, tubers many, large.
	Early Ohio	Do	July 2, 11, 16, 23, 29; Aug. 5	118.0	314.7	Tubers large, uniform in size.
	Burbank	Do	Do	131.0	349.3	Plants vigorous, tubers many, large.
	Early Ohio	Do	July 2, 16; Aug. 5	92.0	245.3	Tubers many, not large.
	Burbank	Do	Do	110.0	293.3	Tubers many, rather large.
1912	Early Ohio	Check, lead arsenate		38.5	102.7	
	Raleigh	Do		54.5	145.3	
	Early Ohio	Do		37.5	100.0	Inoculated with *Bacillus atrosepticus*.
	Raleigh	Do		61.0	162.7	Do.
	Early Ohio	5–5–50	July 10, 24; Aug. 13	32.0	85.3	4–4–50 used first time.
	Raleigh	Do	Do	56.0	149.3	Do.
	Early Ohio	6–6–50	Do	31.0	82.7	4–4–50 used first time.
	Raleigh	Do	Do	58.0	154.7	Do.
	Early Ohio	Lime sulfur	Do	27.5	73.3	1:30 Commercial.
	Raleigh	Do	Do	33.0	88.0	Do.
	Early Ohio	Iron sulfate	Do	27.5	73.3	
	Raleigh	Do	Do	48.0	128.0	
1913	Early Ohio	Check, lead arsenate	July 16	88.0	234.7	
	Rural	Do	July 31	82.0	218.7	
	Early Ohio	5–5–50	July 3, 16, 31; Aug. 14	70.0	186.7	4–4–50 used first time.
	Rural	Do	Do	75.0	200.0	Do.
	Early Ohio	Lime sulfur	Do	70.0	186.7	
	Rural	Do	Do	82.0	218.7	
	Early Ohio	Iron sulfide	Do	73.0	194.7	
	Rural	Do	Do	88.0	234.7	

* Figures 5–5–50, etc., refer to pounds of copper sulphate and lime, and gallons of water, respectively, in bordeaux mixture.

TABLE VI—*Continued*

Year	Variety	Spray used	Dates of spraying	Total yield		Notes
				Per plot	Rate per acre	
				Pounds	Bushels	
1914	Early Ohio	Check.		51.0	136.0	
	Rural	Do		71.5	190.7	
	Early Ohio	5–5–50	June 19; July 15, 29	62.0	165.3	4–4–50 used first time.
	Rural	Do	June 19; July 15, 29; Aug. 5	114.0	304.0	Do.
	Early Ohio	Lime sulfur	June 19; July 15, 29; Aug. 12	52.0	138.7	
	Rural	Do	Do	101.0	269.3	
	Early Ohio	Iron sulfide	Do	55.0	146.7	
	Rural	Do	Do	100.0	266.7	
	Early Ohio	Tonicide, 5–50	July 15, 29; Aug. 12	51.0	136.0	
	Rural	Do	Do	87.0	232.0	
	Early Ohio	Tonicide, 7–50	Do	47.0	125.3	
	Rural	Do	Do	82.0	218.7	
1916	Early Ohio	Check, paris green	July 16	140.00	93.3	Plots all 4 square rods.
	Rural	Do	Do	109.5	73.0	
	Early Ohio	Check, lead arsenate	Do	162.5	108.3	
	Rural	Do	Do	107.5	71.7	
	Early Ohio	5–5–50	July 31; Aug. 15	176.0	117.3	
	Rural	Do	Do	152.0	101.3	
	Early Ohio	Tonicide, 12–50	Do	179.0	119.3	
	Rural	Do	Do	217.5	145.0	
1917	Early Ohio	Check, paris green	July 9, 20	171.0	114.0	
	Rural	Do	Do	140.0	93.3	
	Early Ohio	Check, lead arsenate	Do	173.0	115.3	
	Rural	Do	Do	145.0	96.7	
	Early Ohio	5–5–50	July 26; Aug. 9, 21	240.0	160.0	
	Rural	Do	Do	193.0	128.7	
	Early Ohio	4–4–50	Do	204.0	136.0	
	Rural	Do	Do	174.5	116.3	
	Early Ohio	3–3–50	Do	193.0	128.7	
	Rural	Do	Do	183.0	122.0	
	Early Ohio	2–2–50	Do	198.5	132.3	
	Rural	Do	Do	163.5	109.0	
	Early Ohio	Tonicide, 12–50	Do	212.0	141.3	
	Rural	Do	Do	170.5	113.7	

TABLE VI—*Continued*

Year	Variety	Spray used	Dates of spraying	Total yield		Notes
				Per plot	Rate per acre	
				Pounds	Bushels	
1918	Early Ohio	Check, lead arsenate	June 20, 28	122.0	89.4	
	Rural	Do	Do	97.0	63.8	
	Early Ohio	5–5–50	July 19, 29	241.2	176.9	
	Rural	Do	July 19, 29; Aug. 13	212.5	155 8	
	Early Ohio	2–2–50	June 25; July 19, 29	183.7	134.7	Poison used in first spray.
	Rural	Do	June 25; July 19, 29; Aug. 8	197.0	144.4	Do.
	Early Ohio	3½–3½–50	July 19, 29	191.7	140.6	
	Rural	Do	July 19, 29; Aug. 8	163.7	120.8	
1919						
Plot 1	Rural	4–4–50	CDEF†	155.0	100.0	See discussion for 1919 later, also other data.
2	Do	Do	DEF	114.5	73.8	
3	Do	Do	EF	124.0	79.9	
4	Do	Do	ACEG	125.0	80.6	
5	Do	Poison only	Check	102.0	65.7	
6	Do	4–4–50	AB	113.5	73.1	
7	Do	Do	ABC	117.5	75.7	
8	Do	Do	ABCD	107.5	69.3	
9	Do	Do	ABCDE	120.0	77.3	
10	Do	Do	ABCDEF	133.0	84.7	
11	Do	Poison only	Check	114.5	73.8	
12	Do	4–4–50	ABCDEFG	150.7	97.1	
13	Do	Do	ABCDEFG	130.7	83.2	
16	Do	Do	BCDEFG	116.3	74.9	
17	Do	Poison only	Check	103.5	66.7	
18	Do	4–4–50	CDEFG	121.2	78.1	
19	Do	Do	DEFG	114.7	74.0	
20	Do	Do	EFG	103.0	66.4	
21	Do	Do	FG	104.0	67.0	
22	Do	Do	G	105.5	68.0	
23	Do	Poison only	Check	106.5	68.6	
24	Do	Do	Check	116.5	75.0	

† Letters represent time of spraying: thus A spray in all cases was applied June 25, B, July 8, C, July 16, D, July 25, E, Aug. 5, F, Aug. 15, and G, Aug. 25.

DISCUSSION OF RESULTS

1888. While Professor Green used a much stronger bordeaux mixture (32:60:73) than is at present recommended, the results were striking. No insecticide was added to this mixture. The thick mixture was applied with a broom, with the result that the leaves were densely coated, in contrast to the present-day high-pressure mist of thin spray material. The weather and rain, however, no doubt distributed the mixture over the foliage, and at least removed the excess, and the plants assumed "a decided dark, healthy color." These results obtained by Mr. Green, and many results obtained since on plots sprayed by hand, indicate that the use of a considerable amount of mixture, even with low pressure, may give good results. High pressure of course allows a better distribution of the mixture.

1893. Professor Green reduced the strength of his mixture in 1893 to 6:4:44. He noted, however, that the mixture might be used without the half dilution with water, i.e., in 6:4:22 strength. He recommended preparation a few days before using, which is contrary to present-day usage, and evidently a broom was again used for application. Very good results were nevertheless obtained.

1894. Detailed figures covering the results secured in 1894 are not available. Professor Green stated, however, that only slight increases in yield were obtained. A 5-5-50 bordeaux mixture was used. The extreme dryness of the summer prevented the normal growth of potatoes.

1895. Despite the fact that Professor Green reported that the spraying was done carefully with a 5-5-50 mixture in 1895, the yield in some cases was less from the sprayed plots than from the unsprayed. It is impossible to give reasons for the lack of increase in yield on sprayed plots.

1908. The experiments carried on by Mr. Kohler as summarized previously gave consistent and favorable results from the use of bordeaux mixture.

1909. The results secured by Mr. Kohler from spraying a late variety of potato were favorable, and were similar to the results obtained in 1908. The weather conditions in 1909 were favorable to potato production. Preliminary experiments were also carried out in 1909 by the Division of Plant Pathology and Botany but detailed results from this work are not available.

1910. The experiments carried on for the Division of Horticulture by Mr. Kohler again gave good results, consistent with those obtained the preceding two years. Unusually large yields were secured

from the plots sprayed with bordeaux mixture by the section of plant pathology. These results with the different applications of spray were consistent. The check plots were too few to permit drawing very definite conclusions. The experimental plots were also somewhat small, being only one square rod for each test in this and some succeeding years. The sprayed plots remained green considerably longer than the unsprayed in the tests carried out by the Division of Plant Pathology and Botany, and the increased yield was largely due to the greater size of individual tubers.

1911. Mr. Kohler secured results again indicating the value of spraying late potatoes, and obtained considerable increase in yield on the Early Ohio variety.

The detailed figures for the plots sprayed by the section of plant pathology are not available. Partial results, however, indicate a considerable increase in yield from spraying.

1912. The experiments in 1912 and succeeding years were carried on only by the section of plant pathology. The results obtained in 1912 were in sharp contrast to those of the previous years, since the check plots yielded more than the sprayed plots. The source and history of the seed tubers used in this and several other years is not known, and the plots were not sufficiently replicated. The lime-sulfur and iron-sulfide sprays did not increase yield.

1913. The results were uncertain in 1913. Lime-sulfur and iron-sulfide sprays gave better results than bordeaux, and the highest yield from the early variety was obtained on the check plot. Some injury from early blight was reported, but this disease caused only slight damage to the spray plots.

1914. Considerable increase in yield from the application of bordeaux, particularly on the late variety, was obtained in 1914. Smaller increases in yield resulted from the use of other fungicides.

Coöperative tests were run at Little Falls in 1914, and are summarized later.

1915. While spraying experiments were carried out on a considerable scale, a serious infestation of the plots by pocket gophers renders impossible the interpretation of results. Information is obtainable as to cost of spraying, however, and for this and other years is summarized later.

1916. Larger plots, four square rods each of early and late potatoes for each test, were used. All plots were planted May 31. The plants remained green considerably longer on the plots sprayed with bordeaux and tonicide.

1917. Tests with different strengths of bordeaux mixture at University Farm in 1917 gave results indicating that stronger mixtures are the most satisfactory. All plots of the late variety were planted

May 5, the check plots of Early Ohio on May 12, others May 14. Results were fairly consistent throughout. Growing conditions were favorable, except that an early frost killed the vines of the late variety and checked the growth of tubers. This no doubt lessened the increase on the sprayed plots of the late variety, since the vines were dying on the unsprayed plots of the late variety at the time of frost, whereas the sprayed plots were still green. Tonicide again gave good results, altho not equal to those from 5-5-50 bordeaux. The yields were fairly good at University Farm, tho the seed used was grown the previous year on the station plots.

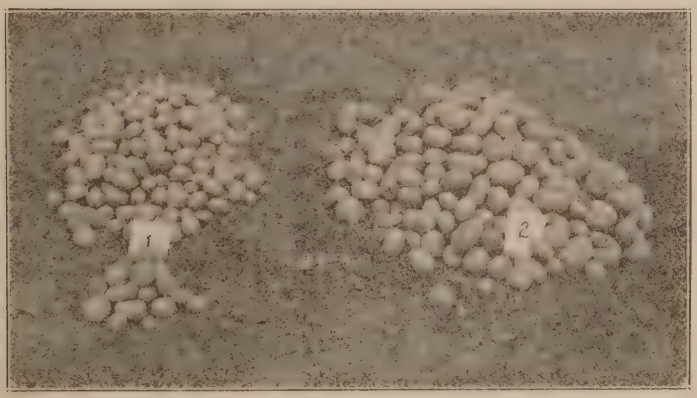

Fig. 1. Results at University Farm, 1918
1, Unsprayed; 2, Sprayed with bordeaux mixture. Yield was much increased by spraying. The variety used was Rural New Yorker.

1918. The seed tubers used for the spray plots in 1918 were obtained from northern Minnesota in order to be sure that the stock was vigorous. The Early Ohio variety was obtained from near Glyndon, Clay County, and the tubers were selected for freedom from disease. The Rural New Yorkers were grown in 1917 near Deer Creek, Otter Tail County, and were treated with corrosive sublimate by the Division of Horticulture. By accident this treatment had been for 12 hours, but the sprouts were uninjured, and the stand was nearly perfect. The tubers were planted May 11, except those in the check plots, which were planted May 15. The plants emerged from May 28 to June 1. No late blight occurred, and but little early blight. Tipburn became quite serious on the Early Ohio variety, and the season was such as to cause rather early maturity of the plants. On the early variety by August 8 only the plot sprayed with 5-5-50 bordeaux mixture showed foliage still fairly green.

To avoid, so far as possible, sources of error from different yields of outer rows, the plots were all planted continuously without the interposition of check rows of different varieties. The rows were three feet apart, for convenience in cultivation and spraying. The hills were carefully spaced 16½ inches apart, thus giving 12 hills to the rod. The rows were 8 rods long, 4 rods being planted to the early variety and 4 rods to the late variety, and check hills were planted at the ends of the rows. No extra space was left between plots in any direction. The yield was taken separately from the two outer and the three inner rows in each plot, and each plot of about four square rods was divided at the middle in digging, so that what might be considered four replications of yield were obtained for each spray plot. Since each plot consisted of 5 rows, 3 feet apart and 4 rods long, the area was only 10/11 that of four square rods, and the yield was calculated accordingly. The tubers were washed before being weighed, since data were desired on the amount of black scurf present. Other unsprayed plots, planted from the same seed and in the same way, were also used as checks, the only evident factor tending to alter the yield being the slight difference in time of planting.

The yield in pounds of tubers produced on outer and inner rows on the different spray plots of the Early Ohio variety is given in Table VII.

TABLE VII
YIELDS FROM DIFFERENT PARTS OF EARLY OHIO SPRAY PLOTS, 1918

Spray used		Number and weight, after washing, of tubers produced							
		Two outer rows				Three inner rows			
		First half		Second half		First half		Second half	
Strength	No. Appl.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
			Lbs.		Lbs.		Lbs.		Lbs.
5–5–50	2	206	48.2	183	47.0	313	79.7	265	66.2
2–2–20	3	203	42.5	169	38.7	230	46.2	262	56.2
3½-3½-50	2	186	38.2	158	35.5	299	67.0	243	51.0
Check		90	16.2			156	27.2		

The results are fairly consistent, and show the value of 5-5-50 bordeaux mixture under the conditions of the experiment. The number and the weight of tubers produced were increased on the sprayed plots. That the yield of the check for the spray plot was not unduly low is shown by the fact that the average yield from 28 counts on other plots of Early Ohio not sprayed, from the same seed stock, was 82.7 bushels per acre.

1919. The general spray plot in 1919 was planned to conform to the recommendations of a committee of the advisory board of American plant pathologists. The bordeaux mixture was applied at different dates with a view not only of obtaining data on the effect of spraying upon the yield, but also on the number of times to spray and the schedule to be followed. The field was planted in rows 3 feet apart, 90 feet long, and 4-4-50 bordeaux was applied as listed in Table VIII. The conditions were uniform, except that the seed tubers used were not very vigorous. They were obtained from near Anoka, Minnesota. They were planted with a potato planter on May 14, and were sprayed with a power sprayer. Some tipburn occurred, a little early blight, but no late blight. The Colorado beetle was common at first, leafhoppers appeared July 1, and aphids July 15.

TABLE VIII
SUMMARY OF YIELD OF SPRAY PLOTS, 1919

No. sprays	Plots	Average yield	Increase over check		
		Pounds	Pounds	Bu. per acre	Per cent
7	12 and 13	140.75	32.15	20.7	26.6
6	10 and 16	124.12	15.52	10.0	14.3
5	9 and 18	120.67	12.07	7.7	11.1
4	1, 4, 8 and 19	125.56	16.96	11.0	15.6
3	2, 7 and 20	111.67			
2	3, 6, and 21	113.80			
1	22	105.50			
0	5, 11, 17, 23, and 24	108.60			

While the yield was small because of low germination of the tubers, a consistent increase was obtained. Four applications would appear to be sufficient under ordinary conditions, applied at about two-week intervals beginning about the middle of July, unless late blight threatens.

In 1919 another series of experiments was run with tubers saved from the 1918 spray plots. This was for the purpose of testing the effect of spraying on the yield the subsequent year, that is, whether spraying results in increased vigor of the progeny. Wellington reported that tubers from sprayed plants on University Farm gave an increase in yield the following year. Both Early Ohio and Rural varieties were used. This seed was obtained from northern Minnesota in the spring of 1918. Nearly four square rods of each variety from plants sprayed in 1918 and the same area of each variety from plants not sprayed in 1918, were planted May 13, 1919. Two square rods of each lot, sprayed and unsprayed in 1918, were sprayed 4 times, on July 8, 19, and 30; and August 15, 1919. The other two square rods of each lot were left unsprayed in 1919. Table IX gives the plan and results of the experiment.

TABLE IX

Effects of Spraying on Yield the Succeeding Year

Variety	No. hills	Sprayed 1918	Sprayed 1919	Yield	Rate per acre	Gain or loss from spraying in 1918
				Pounds	Bushels	Bu. per acre
Early Ohio.....	119	Yes	Yes	133.50	198.5	30.9 gain
Early Ohio.....	118	No	Yes	114.25	167.6	
Rural.....	118	Yes	Yes	100.00	146.7	8.0 loss
Rural.....	115	No	Yes	105.50	154.7	
Early Ohio.....	119	Yes	No	111.25	163.1	41.7 gain
Early Ohio.....	118	No	No	82.75	121.4	
Rural.....	114	Yes	No	100.50	147.4	7.3 gain
Rural.....	119	No	No	95.50	140.1	

These results indicate that Early Ohio seed tubers from sprayed plants gave considerably better results the succeeding year than seed tubers from unsprayed plants. There was no appreciable difference in 1919 in the appearance of the plants or in the amount of disease between those sprayed and unsprayed in 1918. The Rurals showed no effect, on the average, as a result of spraying the preceding year.

Considering the effect of spraying in 1919 on the yield, it will be seen that there was an increase at the rate of 35.4 bushels per acre from spraying the Early Ohios in 1919, both plots having been sprayed in 1918; an increase of 46.2 bushels from spraying in 1919, both plots having been unsprayed in 1918. Spraying both in 1918 and 1919 resulted in an increase of 77.1 bushels per acre over plots unsprayed both years. For the Rurals the figures would be 4.7 bushels loss and 14.6 and 6.6 bushels per acre gain, respectively. The averages for the year 1919 are taken from the above figures and from those listed previously.

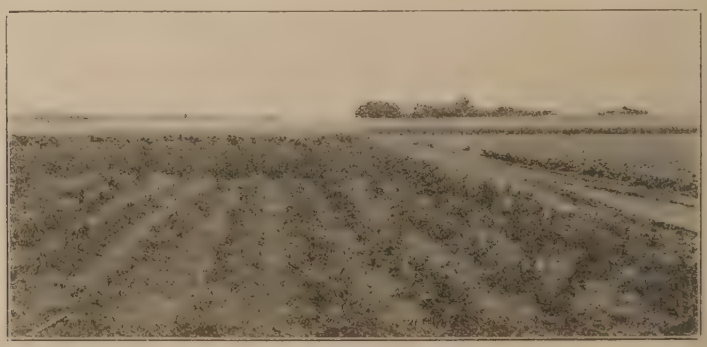

Fig. 2. Spray Plots at University Farm

Right, sprayed with 5-5-50 bordeaux mixture; left, sprayed with 2-2-50 bordeaux mixture. Early Ohio variety. Stronger bordeaux keeps the vines green longer and increases yield.

TABLE X

AVERAGE GAIN OF LOSS FROM EXPERIMENTAL SPRAYING AT UNIVERSITY FARM

Year	Spray and strength	Variety sprayed	Source of data	Average gain or loss of sprayed plots per acre
				Bushels
1888	32:60:73 Bordeaux	Polaris	Green	104
1893	6:4:44 Bordeaux	Burbank	Green	50
1894	5:5:50 Bordeaux		Green	Slight gain
1895	Do	Late varieties	Green	11.7 loss
	Do	Early Varieties	Green	3.1 loss
1908	Do	Raleigh	Kohler	10.6
1909	Do	Raleigh	Kohler	16.8
	Do	Early Ohio	Kohler	4.5
1910	Do	Raleigh	Kohler	35.8
	Do	Early Ohio	Kohler	87.2
	Do	Burbank	Pl. Path	255.9
	Do	Early Ohio	Pl. Path	130.3
1911	Do	Late varieties	Kohler	67.7
	Do	Early varieties	Kohler	19.9
	Lime sulfur 1:32	Raleigh	Kohler	63.3
	Lime sulfur 1:40	Raleigh	Kohler	55.2
1912	5:5:50 and	Raleigh	Pl. Path	20.0 loss
	6:5:50 Bordeaux	Early Ohio	Pl. Path	17.3 loss
1913	5:5:50 Bordeaux	Rural	Pl. Path	18.7 loss
	Do	Early Ohio	Pl. Path	48.0 loss
1914	Do	Rural	Pl. Path	113.3
	Do	Early Ohio	Pl. Path	29.3
1916	Do	Rural	Pl. Path	29.0
	Do	Early Ohio	Pl. Path	16.5
1917	Do	Rural	Pl. Path	33.7
	Do	Early Ohio	Pl. Path	45.4
1918	Do	Rural	Pl. Path	92.0
	Do	Early Ohio	Pl. Path	87.5
1919	4:4:50 Bordeaux	Rural (4 sprays)	Pl. Path	8.9
	Do	Rural (7 sprays)	Pl. Path	20.7
	Do	Early Ohio	Pl. Path	52.9

The increase would be greater in some cases, 1908 and 1909 for example, if the average did not include results from plots sprayed less frequently.

The average increases from spraying with bordeaux for fourteen years for which definite figures are available are 17.8 bushels per acre for the late varieties and 35.3 bushels per acre for the early varieties. Excluding the disproportionately high figures obtained in 1910 on the Plant Pathology plots, the increases are 31.8 bushels and 27.1 bushels, respectively.

WEATHER CONDITIONS AND VALUE OF SPRAYING

Late blight has never been a serious factor in the spraying experiments carried on at University Farm. Indeed, only in 1915 was any late blight reported to be present on the spray plots, and then not in any quantity. The increase or decrease in yield obtained must be

attributed to other factors. Table XI is summarized from weather reports of the St. Paul station of the United States Weather Bureau.

Record maxima and minima are indicated in bold-face type. In 1894 two sucessive low records for precipitation, and a high record for temperature, are sufficient to explain the uncertain results secured. The average gain or loss in yield is taken from Table X, and obtained by averaging the results from early and late varieties, where results from both were obtained, except that in 1910 only the results obtained by Mr. Kohler are included. There is no apparent relationship between the weather conditions and gain or loss from spraying, and evidently other than meteorological factors were operating to induce the variations noted.

TABLE XI

SUMMARY OF WEATHER CONDITIONS AND EFFECT OF SPRAYING

Year	Precipitation			Temperature, F.			Average gain or loss from spraying
	June	July	August	June	July	August	
	Inches	Inches	Inches	Degrees	Degrees	Degrees	Bu. per acre
1888	1.95	5.55	2.23	66.8	73.1	67.4	104
1893	2.00	1.68	2.40	71.4	73.4	69.0	50
1894	1.51	**0.13**	**0.36**	72.2	75.8	72.2	Slight gain
1895	4.18	4.12	2.59	66.9	70.0	69.8	7.4 loss
1908	5.14	2.94	1.07	64.6	72.2	68.4	10.6
1909	4.41	3.66	2.89	66.8	70.8	73.2	10.6
1910	0.91	0.99	0.98	71.4	74.2	69.1	36.5
1911	5.79	5.15	5.53	71.8	70.6	66.1	43.8
1912	1.10	4.02	4.40	64.6	70.5	66.5	18.6 loss
1913	3.05	6.11	1.59	70.0	69.9	72.2	33.3 loss
1914	6.49	0.95	4.48	66.2	74.6	68.8	71.3
1915	3.58	4.53	3.98	62.4	67.1	65.4	...
1916	3.79	0.75	1.60	62.7	**78.2**	71.6	22.7
1917	3.79	4.12	2.82	62.8	72.4	66.5	39.5
1918	2.81	5.05	5.19	66.3	69.9	70.4	89.7
1919	4.40	7.47	2.22	70.0	73.6	68.5	27.5
Normal	4.41	3.40	3.46	67.4	72.1	69.5	....

EXPERIMENTS WITH BORDEAUX MIXTURE AT SUBSTATIONS IN MINNESOTA

T. M. McCall has carried on spraying experiments with 5:5:50 bordeaux mixture for several years at the Northwest Experiment Station, at Crookston. He reports (12) that as a result of spraying 3 times each year for 7 years the average yield was 116.44 bushels per acre as compared to 95.7 bushels on the check plot. This increase in yield was obtained in the absence of late blight. Early Ohio potatoes were grown. Altho Crookston is a favorable region for growing Early Ohios, a marked increase in yield follows the use of bordeaux mixture.

M. J. Thompson, superintendent at the Northeast Substation, Duluth, reported (13) for the first year's results an increase of 29 bushels per acre from spraying. These results from Crookston and Duluth are similar to those from St. Paul.

COOPERATIVE SPRAYING EXPERIMENTS

An arrangement was made in 1914 whereby John Klinka, at Little Falls, sprayed half-acre plots of Green Mountain and Rural New Yorker varieties, leaving checks without applying bordeaux mixture. Two plots were sprayed four times, July 8, 31, August 12 and 26, and two plots were sprayed twice, July 31 and August 15. A 4:4:50 mixture was used for the first spray in all cases and the 5:5:50 formula for all succeeding applications. Only 37½ to 40 gallons of spray per acre was applied at each application. The plots sprayed 4 times averaged 101.7 bushels per acre; those sprayed twice yielded an average of 75.2 bushels per acre, and the checks 82.3 bushels per acre. While these results are not especially consistent, they indicate an increase from four applications, even tho too little bordeaux was used. No late blight occurred, and early blight did little damage.

Coöperative spraying experiments were carried out in 1915 in Hennepin County by K. A. Kirkpatrick, county agent, and the section of plant pathology. The full details of the method of applying the bordeaux mixture, number of applications, etc., are not available. The average increase from spraying obtained by five growers was about six bushels per acre.

Further experiments were performed on the farm of Mr. Kroetz, near Wayzata, Hennepin County, in 1918, in coöperation with S. A. Graham of the Department of Entomology. A 100-gallon sprayer was used with two nozzles to the row. The field was about 7½ acres of the Rural New Yorker variety. The first spray was applied July 23. An insecticide alone, 4 pounds lead arsenate and 2 pounds paris green to 100 gallons of water, a 2:3:50 bordeaux plus the above proportions of insecticide, and a 4:5:50 bordeaux plus the insecticide were used. The field was sprayed in alternating four row plots, i.e., on the first four rows insecticide alone was used, on the next four rows, the 2:3:50 mixture, and on the next four the 4:5:50 mixture, and this was repeated across the 115 rows constituting the field. About 40 gallons of spray was applied per acre.

A second spray of 4:5:50 bordeaux without insecticide was applied August 9 on the same rows sprayed with this mixture previously. The tops were large and green, and suffered little leaf injury. No difference in the character of the vines on the different plots was to be observed up to the time the vines were killed by frost.

Yields could be obtained on only a part of the field. The yields are reasonably accurate, and at least comparable.

Average yields obtained were as follows:

	Bushels per row	Bushels per acre
4:5:50	8.86	214.4
2:3:50	8.76	212.0
Poison only	7.9	191.2

Mr. Graham also applied bordeaux mixture to Early Ohio potatoes, in combination with various insecticides. The application was made similarly to that on the late variety, but early in the season, and comparable results were obtained; an average slight increase over the plots sprayed with bordeaux mixture alone.

These coöperative tests indicate that an increase in yield may be expected to follow the use of bordeaux. The increases were obtained in the absence of late blight; in other words, the "insurance paid for itself."

THE USE OF BORDEAUX MIXTURE BY POTATO GROWERS IN MINNESOTA

Many growers throughout the state have tried bordeaux mixture in a rather small way at one time or another. In numerous cases, however, these growers have not been sufficiently convinced of the value of this spray to use it year after year. Certain growers, on the other hand, have found that the mixture is of much value in potato production. The following reports have been received from growers in Minnesota who have used bordeaux mixture on their farms.

Floyd Riggs, Bertha, Minnesota, has used bordeaux mixture for several years. In 1917 he found that the rows which were not sprayed yielded only about two thirds as much as those sprayed. Mr. Riggs reports that one could easily determine the rows which were not sprayed, as they withered much earlier. He obtained about 180 bushels of Early Ohios per acre. In 1918 he obtained about 150 bushels per acre, a considerably better yield than that from unsprayed fields in the vicinity. In 1919 Mr. Riggs sprayed 20 acres 5 times and 20 acres 3 times, and reported that those sprayed 5 times looked much better than those sprayed 3 times. An inspector who visited Mr. Riggs' farm reported that the fields looked better than unsprayed fields in the vicinity.

Mr. Riggs uses stock solutions in making up his spray mixture. In his earlier work he used 60 gallons per acre for each spray, but in 1919 he used 100 and 150 gallons per acre each spray, at a pressure of 150 to 200 pounds with three nozzles per row. He sprays at 7- to

9-day intervals. Figure 4 shows spraying operations on Mr. Riggs' farm. He finds spraying profitable, and considers that the lime added to the field is of value on soils that need lime.

F. C. Cosgrove, of Bertha, has also had favorable results from spraying in 1919.

Fig. 3. Apparatus Used by Mr. Steward, Princeton, Minn., for Mixing Bordeaux (Illustration by courtesy of Mr. Steward)

Spraying was carried out in 1919 on several farms near Princeton, under the direction of Verne Steward. Bordeaux mixture was applied three times with a triple-cylinder sprayer with 3 nozzles per row. Forty gallons per acre was applied the first time, and 100 gallons per acre the second and third times. A special arrangement, illustrated herewith, was used for mixing the bordeaux from stock solutions.

Mr. Steward reported about 25 per cent increase from spraying Cobblers. In one case a 50 per cent gain was obtained by spraying Bliss Triumphs. These gains were realized in the absence of late blight. Mr. Steward states that he has proved to his satisfaction the value of spraying.

METHODS OF PREPARATION AND APPLICATION OF BORDEAUX MIXTURE

We recommend that a 5:5:50 mixture be used for potatoes. The first figure indicates the number of pounds of copper sulfate, the second figure the number of pounds of lime, and the third figure the number of gallons of water. Use the crystals of copper sulfate (bluestone or blue vitrol, poison) and unslaked or stone lime (quick lime). Better results will follow if clean water is used rather than dirty water from a pond.

Two methods may be used in making the bordeaux mixture. If only small quantities (100 gallons or less) are needed, it may be made directly. To make 50 gallons, for example, put 5 pounds of the copper sulfate in a coarse sack and hang it in a wooden barrel containing 25 gallons of water so that the sulfate is just below the surface of the water. It will dissolve in about an hour if suspended in this way. Slake 5 pounds of good stone lime slowly in a little water and as soon as it has slaked, add enough water to make 25 gallons. Either of these mixtures will keep, but should be covered to avoid evaporation of the water. To make the bordeaux, stir the lime mixture and pour it and the bluestone solution together through a strainer into the sprayer so that the streams mix in pouring. This gives a blue solution. To test it for a possible excess of copper, put a newly filed piece of iron or steel into the mixture for a moment. If it has a copper coating, more lime should be added. The mixture should be used the same day it is made, unless a little sugar be added to preserve it. About half a pound of sugar will preserve 50 gallons of bordeaux.

When spraying is done on a larger scale, it is most convenient to use stock solutions. Dissolve the bluestone as previously mentioned, but use one pound of bluestone to each gallon of water, or 50 pounds for a 50-gallon barrel. Slake the lime and add water so that there is a pound of lime for each gallon of water. Both these stock mixtures will keep indefinitely. The barrels should be covered to avoid evaporation, or mark the surface of the water on the barrel and add water up to this mark before using. Then to make 50 gallons of bordeaux, use 5 gallons of bluestone solution, 5 gallons of lime mixture, and 40 gallons of water. Use either barrels elevated from the ground, as illustrated in Figure 3, or the following simple method: Fill the spray tank about one third full of water, add through a strainer the required amount of stirred stock solution of lime (5 gallons for a 50-gallon tank, or 10 gallons for a 100-gallon tank) then fill tank up to about two-thirds full, add the stock solution of bluestone (same quantity as lime mixture) then fill the tank with water.

Blue vitrol is poisonous to man or animals if taken internally. The solution can not be made in a metal container since it corrodes metal. Blue vitrol that has "slaked," or become powdered, is slightly stronger than the crystals.

Paris green or arsenate of lead may be combined with the bordeaux mixture when an insecticide is needed. Add the amount of poison needed just as if the bordeaux mixture were water.

Spraying should begin when the potato plants are about a foot high, in the latter part of July or early August. Applications should be made at about ten-day intervals, unless late or early blight threatens

to be serious, when more frequent spraying is advisable. The number of applications depends somewhat on the weather conditions. It is important to keep the vines fairly well covered with the mixture and from 50 to 100 gallons or more per acre should be applied each time. Three nozzles for each row and larger quantities of bordeaux should be used when the potato plants become large.

Fig. 4. Spraying on the field of Mr. Riggs, Bertha, Minn.
The use of three nozzles and high pressure covers the vines thoroly.

COST OF SPRAYING WITH BORDEAUX MIXTURE

The cost of spraying varies from year to year with the price of copper sulfate and of labor, etc. Mr. Kohler estimated (11) the cost in 1909 at 60 cents per acre as follows: bluestone at 7½ cents per pound, lime ½ cent per pound, and the cost of preparation and application at 20 cents per acre. The items now would be considerably higher. He figured, similarly, the cost at 72 cents per acre for 1908, and 80 cents per acre for 1910 and 1911.

The cost of materials for the plot experiments in 1915 was figured on the basis of 7 cents for copper sulfate and ½ cent for lime. With the first application of 50 gallons per acre, the cost of materials would be 38 cents per acre, and 75 cents for subsequent sprayings with 100 gallons per acre. Tonicide was figured at 13 cents per pound, which would be $1.56 for an application of 50 gallons of a 12:50 formula, or $3.12 for 100 gallons per acre.

In 1917, for example, the plots were sprayed more heavily, 5 gallons being applied to each 4 square rods. This is at the rate of 200 gallons per acre per spray, or a total of 60 pounds each of copper sulfate and lime per acre for three sprayings. A heavier application costs somewhat more, but appears to pay under University Farm conditions.

The cost was figured for the coöperative experiment as carried out in 1914 on the farm of Mr. Klinka. For spraying a total of 12 half acres this cost was as follows:

Lime, 46 pounds at 1 cent per pound	$0.46
Litmus paper	0.15
Copper sulfate, 46 pounds at 7 cents per pound	3.22
Labor	10.26
Depreciation	1.50
	$15.59

This is an average of $2.60 per spray per acre. The labor item might have been reduced somewhat had a larger acreage been sprayed, but it is evident that labor is a big factor in the cost of spraying. In certain cases, however, the bordeaux mixture may be combined with the essential spraying for insects, and the cost thereby lessened.

Costs, including labor, were about $3 per acre per spray at University Farm in 1919. If larger acreages were sprayed, costs per acre should be reduced somewhat.

USE OF FUNGICIDES OTHER THAN HOME-MADE BORDEAUX MIXTURES

Lime sulfur and iron sulfide did not give good results in our experiments. The commercial bordeaux paste used (Tonicide) gave fairly good results in 1914, 1916, and 1917. Indications are that even when used at a strength of 12 pounds to 50 gallons of water, it is not quite equal to 5-5-50 bordeaux mixture. Commercial mixtures, particularly pastes, may give favorable results if the dilution used is not so great as to reduce too much the strength of copper, and have the advantage of somewhat greater ease of preparation. There is much need of greater standardization of commercial preparations, and the

label indicating strength of copper and of poison, if present, should be carefully considered before purchasing such preparations. Home-made bordeaux mixture has the advantage of considerably less expense, and is the standard for effectiveness. There may be some difficulty in obtaining unslaked lime in some localities, and for small areas commercial mixtures may offer an easy method of preparing a fungicide.

SUMMARY OF RESULTS OBTAINED IN CERTAIN OTHER STATES

Late blight occurs frequently in the northeastern states. Bordeaux mixture has been used there for several years, and it has been repeatedly shown to be necessary as a preventive of late blight, and to pay for itself when late blight is absent. A series of experiments with bordeaux covering twenty years, in Vermont (14), showed an average increase of 105 bushels per acre from sprayed plants. Spraying has repeatedly given large increases in yield in Maine (15). The New York Experiment Station (16) has reported excellent results from spraying, and in Pennsylvania (17) increases on the average of 34 to 45 bushels per acre were obtained from the use of bordeaux. In New Jersey (18), however, spraying has not been found to pay in all cases.

The results from spraying in the north central part of the United States have in general also been favorable, even in the absence of late blight. A five-year average increase of 20 bushels per acre for five sprayings is reported by Iowa (19). Bordeaux mixture has given favorable results in Wisconsin (20) and Michigan (21), particularly for those who make a specialty of growing potatoes.

The average results of spraying in Minnesota are similar to the results obtained in various other states.

EFFECT OF SPRAYING WITH BORDEAUX MIXTURE ON THE POTATO PLANT, ON VARIOUS DISEASES, AND ON INSECTS

The work of Duggar and Cooley (22), Martin (23), and Duggar and Bonns (24), has shown that a film of bordeaux mixture on the leaves of plants increases the rate of transpiration, or water loss, from the leaves. This increase takes place largely at night. It appears to be undecided, however, whether this increase in transpiration will account for the increased yield often reported from sprayed

potatoes in the absence of late or early blight. At any rate a darker green color of sprayed plants is often observable. Lutman (25) found that sprayed leaves were thicker, that the cells contained more chlorophyll, and that the plants remained green longer in the fall than unsprayed plants. Lutman nevertheless concluded that spraying increased the yield principally from prevention of diseases and from lessening insect injury.

Bordeaux mixture prevents late blight and early blight by the action of the copper compound in the mixture. When the spore of a fungus falls on a sprayed leaf, and moisture is present so that this spore can germinate, there is sufficient poison dissolved by the water from the bordeaux to kill the germinating spore. In other words, the spore attempts to grow in a "lake of poison." Spraying must be done before the spores germinate on the leaf, because the spray is a preventive, not a cure.

Some study has been made on the possible effects of spraying on certain potato diseases other than leaf diseases. It was thought possible that sprayed plants might be more thrifty, and thus able better to withstand certain diseases. The relationship of spraying to wilt has been discussed elsewhere (26). In so far as spraying results in the production of more vigorous potato plants, the danger of wilt should be lessened by the use of bordeaux.

Several counts were made in 1918 and 1919 on the percentage of black scurf on potatoes grown on sprayed and on unsprayed plants. The crop on the sprayed plots in 1918 showed as an average of 12 counts, 5.2 per cent black scurf, and on the unsprayed plots an average of 12.3 per cent black scurf from 4 plots. In 1919, however, the average of 3 counts on the crop from sprayed plants was 10.2 per cent black scurf, and only 6.9 per cent on 3 unsprayed plots. So far as our evidence goes, therefore, spraying exerts no appreciable influence on the amount of black scurf on the progeny at University Farm.

Counts were made in 1919 on the number of plants affected with mosaic occurring on the progeny of plants sprayed and unsprayed in 1918. Mosaic may not show until the year after infection, so that the effect of spraying on this disease can best be observed by examining the progeny of sprayed plants. There were 42 mosaic hills in 4 square rods that were planted from tubers obtained from plants sprayed in 1918, and 47 mosaic hills in 4 square rods from plants unsprayed in 1918. The presence of bordeaux on the leaves did not appear to lessen the number of aphids on the leaves in 1919, and aphids may spread mosaic. Bordeaux probably has little effect on the spread of mosaic.

It has recently been shown (27) that "tipburn" of potato leaves is brought about largely by the action of leaf-hoppers. An important effect of bordeaux in preventing tipburn or hopperburn appears to be that of repelling the leaf-hoppers. Preliminary counts made in 1919 on a number of sprayed plants when leaf-hoppers were numerous gave an average of about 8 leaf-hoppers per sprayed plant, and about 38 on each unsprayed plant, altho the plots were adjacent. Bordeaux mixture does not kill the hoppers, but they seem to prefer unsprayed plants.

Flea beetles are also reported to cause less injury to sprayed plants.

CONCLUSION

The results presented in this bulletin demonstrate that a considerable increase in yield, on the average, is obtained from spraying potatoes with bordeaux mixture at University Farm. The results from other parts of Minnesota indicate that spraying is generally of value in increasing yields throughout the state.

Late blight is sometimes serious in various parts of Minnesota. None of the results presented in this bulletin were obtained on plots affected with late blight. Spraying would be of great value in the event of an epidemic of late blight.

Most potato growers are already provided with sprayers for the application of poison. The same sprayers can ordinarily be used for applying bordeaux mixture, altho of course the better sprayers give the better results. Arrangements should be made for attaching 3 nozzles per row for the applications of bordeaux when the plants are large. It can not be said that spraying will pay everywhere in Minnesota in every season, but it is a measure that should be tried by any farmer specializing in potatoes, for the chances are that it will be commercially profitable, and it is the insurance against late blight.

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Dr. Huestis: Put them twelve or fourteen feet apart if you want them to stay there.

Mr. Husser: He says he did it to keep out of mischief but any one that is interested in a good apple ought to get one from Mr. Huestis and try it. We tried them down in southeastern Minnesota, and we find that they blight.

Dr. Huestis: That is, the dwarf?

Mr. Huesser: Yes, sir.

Dr. Huestis: I understood they have blighted, but none have blighted with me.

Mr. Max Pfaender: In regard to the Paradise apple stocks, we have several strains in North Dakota that have been hardy for the last three or four winters, and we have found they can be grown from cuttings like a willow. You can stick in a cutting in the spring and bud it that same fall or you can dig them up in the fall and graft them that winter.

TEACH MAKING OF SIMPLE HOME DEVICES.—Many rural women have been in need of simple instructions in the making of household conveniences, labor-saving devices, and making of small articles for sale, in order to increase the family income. The instructions in rug making, making of baskets, brooms, etc., given to the girls by the home-demonstration agents have also, at many places, been given to the women, resulting in the promotion of home industries and increased earnings. This added income has mainly been used to improve the home or to assist the war work. In several instances the women, who had saved enough from such earnings to purchase the needed furniture, have instead given it to the Red Cross.

DRESS EDUCATION A NEED OF TIMES.—Marion Weller, professor of textiles in the home economics division of the Minnesota college of agriculture, says that three things need to be done to overcome the indifference to and even ignorance of the right kind of buying methods which exist among women shoppers today. There are, she says:

"First, girls and women as consumers must be taught to appreciate and demand quality in yard goods and ready to wear garments. Clothing selection, textile selection, and simple tests for quality must be emphasized.

"Second, a rational system of textile standardization should be established as a guide for women. At least a limited number of fabrics, generally relied upon for certain outstanding clothing uses, should be standardized.

"Third, protective legislation should be passed. Practices of misrepresentation are widespread and flourish in the textile trade. These practices are unchecked by law. Legislation that will protect the consumer or the retail merchant against such fraud does not exist in this country."

Notes on Potato Diseases

G. R. BISBY, UNIVERSITY FARM, ST. PAUL.

The effect of planting seed pieces showing black areas on the cut surfaces. The cut surfaces of potatoes very often bear black, slimy areas caused by bacteria or by yeasts. This spotting occurs when the cut surfaces do not dry thoroughly and rapidly, and thus become provided with a resistant corky "skin." The moisture and juices which are present when the tissue of the potato is cut provide a good medium for these organisms. Even though the organisms may not be sufficiently active parasites to cause a rot of the seed piece, they prevent the corking over of the cut surface, and the set dries out, or soil organisms attack the tuber when it is planted and cause its destruction.

Seed pieces showing some of the black, slimy growth on the cut surface were selected in the spring of 1919. Care was taken to obtain pieces with good eyes, and in which the blackening had not penetrated far into the tissue. These sets were planted on a plot of 166 square feet. The germination was very poor. Those pieces that grew produced spindly, weak plants from the loss of reserve food. Few of the plants grew to normal size. Figure 1 illustrates the plants as they appeared on July 9, 1919. The yield on this plot was at the rate of 21.7 bushels per acre, whereas seed pieces from the same lot which became corked over on the cut surface yielded from 100 to 150 bushels per acre.

Care should be taken to allow the seed pieces to dry thoroughly at once after cutting. Spread the pieces out in a thin layer in a dry place and shovel them over now and then until the surface is corked over. Sacking the potatoes immediately after cutting provides very favorable conditions for the development of rots on the cut surface, and consequently poor stand or weak sprouts.

The effect of sunlight on black scurf. Mr. H. J. Baldwin of Northfield has called your attention to the value of "sun-sprouting" seed potatoes in order to obtain sturdy sprouts that will develop rapidly when planted, and in order to allow the discarding of tubers producing weak sprouts. Mr. Baldwin was at the Experiment Station early in 1919, and suggested that exposure of sunlight might aid in sterilizing the surface of potatoes, since it is well known that many organisms will not survive exposure to the sun's rays. Tests were accordingly made last year to determine the efficacy of sunlight in killing black scurf upon the tubers.

Three lots of Rurals were selected, two lots with black scurf and one without scurf. One lot of tubers with scurf was cut, then exposed to sunlight for about ten days before planting. The other lot with black scurf was exposed about two weeks to the sun's rays, then cut and planted. The lot without black scurf was planted without exposure to sunlight. The amount of black scurf on the progeny of these lots of seed was as follows:

Lot 1—With scurf, cut and exposed, 55.8 per cent scurf on crop.

FIG. 1. Foreground, poor stand and weak plants obtained from planting seed showing black, slimy growth on surface.

Lot 2—With scurf, exposed and cut, 39.1 per cent. scurf on crop.

Lot 3—Without scurf, not exposed, 8.3 per cent scurf on crop.

It is evident from this preliminary test that exposure to sunlight for a few days will not disinfect seed tubers bearing black scurf. The compact masses of fungus on the potatoes are very resistant to disinfectants; even formaldehyde as ordinarily used does not kill many of them.

Light is valuable in starting sprouts on tubers. It is an excellent idea to expose to sunlight the seed potatoes that are to be planted by hand. If either black scurf or scab is present, however, the potatoes should be treated with corrosive sublimate solution before the exposure.

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Plant Materials for the Farm Home

R. H. PEARSE, LANDSCAPE ARTIST, DES MOINES, IA.

In building and planning a home and home grounds, we have to design and plant for future appearance as well as for immediate effect. The reason why some of us make so many mistakes is because we are not trained to anticipate the probable requirements of the future farm home. The farm home has just as much right to be planned and decorated as the city

Before planting. Farm home of R. E. Cappock, West Branch, Ia.

home. The general opinion of landscape work is that it is useful only for city parks, millionaires and city flower gardens. Far be this from the correct program of development. The landscape architect is a home specialist and trained to anticipate futures.

When the architect's building is completed it seldom changes in appearance, the painter's picture and the sculptor's figure remain the same, but the landscape architect's product is a changing process. Each month, year and period of the year brings out a series of changes in appearance, and these expected changes the professional training of a landscape architect is aimed to anticipate.

There is no royal road to beautiful grounds, no hypodermic injection can produce the information necessary to have attractive farm homes.

The Cooperative Potato Spraying Project: Progress Report for 1918, 1919, and 1920

C. R. BIBBY

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THE COOPERATIVE POTATO SPRAYING PROJECT: PROGRESS REPORT FOR 1918, 1919, AND 1920.

G. R. Bisby

The cooperative potato spraying project is one of the problems for cooperative work undertaken by American plant pathologists under the auspices of their War Emergency Board and Advisory Board. The general leadership of this project, and the responsibility for this report, has been assumed by G. R. Bisby, Agricultural College, Winnipeg, Canada (Formerly at the Minnesota Agricultural Experiment Station).

Bordeaux mixture is commonly applied to potatoes in regions in which late blight occurs or threatens each year. Increased yields result in some areas even when late blight is absent. For many regions, however, plant pathologists do not know just what recommendations to make to potato growers regarding the use of Bordeaux mixture and other fungicides.

The War Emergency Board of American Plant Pathologists considered it important that cooperative work be undertaken on a potato spraying project, and the writer was asked in the latter part of June, 1918, to serve as leader. Letters were at once sent out to pathologists in order to place the proposition before them, with inquiries as to past results of spraying potatoes, and a request for suggestions. Considerable information was received in response to these letters.

The Advisory Board of Pathologists decided that this project, lying between experimentation and demonstration, was a favorable one for continued cooperative effort. G. R. Lyman called a meeting of interested pathologists at Chicago on February 15th, 1919, and the spraying project, among others, was discussed. It was decided to draw up a definite field experiment, with the use of standard equipment, spray materials, and methods of application, with a view of obtaining comparable results and an idea of the optimum spraying schedule in the various localities. This field plan, devised largely by C. R. Orton, is partially given below, and was submitted in 1919 to various workers for their reference, although it was realized that few would be able to undertake the full project.

Early in 1920, this project was again brought to the attention of many of the pathologists. With the beginning of 1921, it was decided to publish this report of the work that had been done by those cooperating.

It was considered worth while also to include a brief summary of the present status of spraying throughout the United States and Canada. A summary for each state and province was accordingly submitted to the proper worker with a request that he correct or amplify the statement as applying to his region. This report is, therefore, a review of the problem for many regions, and includes considerable new data that several have been able to add. The greatest credit is due to the various pathologists and others for the generous way in which they have contributed data for the summary, and for the hearty cooperation that practically every worker has manifested in this project. The leader has endeavored to function merely in providing a clearing house for the scattered results. Thanks are due to Messrs. G. R. Lyman, E. C. Stakman, and C. R. Orton for ideas and help of various kinds.

PLANS OF THE PROJECT

The necessity for working in cooperation with the entomologists in potato spraying work is becoming more evident. Leaf hoppers and aphids are now known to cause or to transmit diseases, and the control of the flea beetle by Bordeaux mixture is also of interest to entomologists. The use of the principles developed by agronomists in field technic must be taken into consideration, in the provision of sufficient checks and replications as well as the use of uniform fields and methods. Experiments in commercial fields are particularly valuable in that larger areas can usually be sprayed, and practical grower's equipment and conditions can be taken into consideration. Sufficient checks should, of course, be left, and these arranged so as to give comparable results, e. g., eight rows sprayed, then four rows left unsprayed, rather than one acre sprayed and another acre left unsprayed. Experimental spraying on a small scale is, of course, valuable, and can often be used to advantage in deciding local questions.

The potato spraying project was brought to the attention of the workers during the three years by letters inquiring as to whether opportunity or need existed for testing out the effect of Bordeaux mixture with the suggestion that such results as were secured might be rendered of added value by comparison with other data from similar regions or under similar conditions. No attempt was made to dictate what should be done, and even excessive "organization" of the project was avoided. An outline of the field experiment previously mentioned was, however, sent out for reference in 1919 and 1920, including the recommendations that standard machines capable of maintaining high and uniform pressure be used. A 4-4-50 Bordeaux mixture was suggested, made as follows: fill the tank one-third full of water; add the required

amount of stock solution of lime; fill the tank two-thirds full of water to mix the lime thoroughly; add required amount of stock solution of copper sulphate; and fill the tank with water. This is economical of time and labor unless special elevated tanks have been rigged up for the purpose. Arsenate of lead or other poison should be applied to each plot upon the first appearance of biting and chewing insects.

An outline for the taking of field data was submitted, including records of soil type, dates of planting and spraying, occurrence of diseases and insects with dates and prevalence, pressure used, yield, costs, etc. It was noted that the field might be of any size; but an acre field was suggested, 360 feet by 121 feet. The field might be divided into 30 plots, each plot consisting of 4 rows of potatoes (see table 1). The letters indicate the time each plot is to receive a particular spray; e. g., A—1st spray, E—5th spray, etc. It was suggested that the plots be sprayed at regular intervals beginning when plants were 5 inches high, and repeating every 10 days. It was recommended for experimental purposes that as many applications be made as the season might permit. Plots 5, 11, 17 and 23 are checks to receive only poison for insects. Various plots should indicate the importance of spraying in different parts of the season.

In many cases, it would not be necessary to apply the ten sprays listed on the field plan; and the sprays J, I, etc. could be omitted without affecting the general value of the plan.

The following reports on the status of the use of Bordeaux mixture in the various states and provinces are listed by regions. Where publication of results has been made, a very brief summary is included—the references to bulletin numbers referring to the bulletins of the agricultural experiment station in question. The imperial gallon, used in Canada, is ¼ larger than the U. S. gallon; a Canadian reference to 4–4–40 Bordeaux should be interpreted 4–4–50 in the United States.

SUMMARY OF RESULTS AND STATUS OF THE USE OF BORDEAUX MIXTURE ON POTATOES

Canada: Work of the Dominion Department of Agriculture in Eastern Canada.—G. E. Sanders and his co-workers, particularly A. Kelsall, have recently developed in Nova Scotia a copper dust. They have tried out the "5-2" formula on potatoes, the figures referring to the percentage of metallic copper and metallic arsenic respectively. Twenty pounds of copper sulphate, dehydrated and ground fine, forming 12½ lbs. powder; 7½ lbs. dry arsenate of lime, containing 40 per cent As_2O_5, and 80 lbs. of hydrated lime are mixed. This dust was found to stick well, and when moisture strikes the leaf, a blue Bordeaux is produced. At Frederickton, N. B., the dusted plot yielded 396 bu. per acre; 4–4–40 (4–4–50, U. S. gallon) Bordeaux, 407 bu.; check, 238 bu. At Truro, N. S., dust, 744 bu. per acre; Bordeaux plus poison, 652 bu.; check, 550 bu. (Proc. Ent. Soc. Nova Scotia, **1918:** 32–37, 1919). Their report for 1919 (l. c. **1919:**

TABLE 1.

Plan of Field

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
			A		A	A	A	A	A		A	A	A	A															
					B	B	B	B	B		B	B	B	B	B											B			
C			C			C	C	C	C		C	C	C	C	C		C												
D	D						D	D	D		D	D	D	D	D		D	D								D			
E	E	E	E					E	E		E	E	E	E	E		E	E	E								E	E	E
F	F	F							F		F	F	F	F	F		F	F	F	F						F	F	F	F
			G								G	G	G	G	G		G	G	G	G	G							G	G
												H	H	H	H		H	H	H	H	H		H			H			H
			1										I	I	I		I	I	I	I	I		I	I					
														J	J		J	J	J	J	J		J	J	J	J			

77–94, 1920) gives further results. The yields of potatoes obtained in 1919 average somewhat less from dust than from Bordeaux, but insects well controlled by dust. Late blight control not perfect if less than 5 per cent of metallic copper is used in the dust. Some evidence that the "stimulating effect" of the dust on the plant is greater than that from Bordeaux. Sanders and Brittain consider (Proc. Ent. Soc. N. S., **1916:** 55–64, 1917), that arsenic compounds have their efficiency reduced when added to Bordeaux; but that sodium compounds increase the effectiveness of poison, perhaps by rendering the leaves more appetizing to insects. Sanders and Kelsall recommend equal parts of $CuSO_4$ and lime in wet Bordeaux for potatoes; but find a mixture containing 3 to 5 times as much lime as copper valuable for apple (l. c., **1918:** 69–75. 1919; see also pp. 51–61). Other observations by the same workers in Agr. Gaz. Can. **7:** 10–12, 1920, and Proc. Ent. Soc. N. S., **1919:** 21–33. 1920.

Wm. Blair reported in 1892 some average increase at Nappan, N. S., from spraying potatoes with about a 3–2–11 Bordeaux. (Canada Cent. Exp. Farm. Report **1892:** 187). Other data in the reports for **1893**, p. 222, and for **1900**, p. 335. W. T. Macoun reports (l. c. **1904:** 131–132; Bull. 49) an increase of 92½ bu. per acre as a result of 4 and 5 applications of Bordeaux at Ottawa in 1901, 1902, and 1904. He also found (l. c. **1905:** 111–121) Burgundy mixture 6–7½–40 did not injure potato leaves; but that the results were hardly as good as from Bordeaux. Other data in the Central Exp. Farm Reports **1892:** 161–164; **1908:** 126; **1910:** 251–284; **1916:** 1147–1149.

H. T. Güssow writes that the Dominion Department of Agriculture has for some years been devoting efforts to bring about the general use of thorough spraying in the Maritime Provinces and in Quebec.

Prince Edward Island.—Late blight common. P. A. Murphy reported (Can. Dept. of Agr., Circ. 10, 1916; Agr. Gaz., Can. **4:** 942, 1917) 97 bu. per acre increase from 5 applications of Bordeaux in 1915. In 1916, no increase in yield from spraying; but rot much reduced. T. Ross reported (Agr. Gaz., Can. **2:** 334, 1915) about half the growers used Bordeaux. G. O. Madden writes that there is no data as to the effect of Bordeaux when late blight is absent.

Nova Scotia.—Late blight common, first appearing after 1877. Scarcely any of the larger growers now attempt to grow the crop without spraying (R. L. Fuller, Agr. Gaz., Can. **2:** 334, 1915). See data previously given.

New Brunswick.—Faithful use of Bordeaux necessary. (J. B. Daggett, Agr. Gaz., Can. **2:** 334, 1915). B. Baribeau writes that he has no data as to the value of Bordeaux in the absence of late blight. See also data previously given.

Maine.—W. J. Morse reports late blight usually present, often serious. Early blight and tipburn common, more particularly in the southern part of the state. Tipburn apparently physiological. Necessity of spraying with Bordeaux abundantly proved (Me. Bulls., 73, 87, 98, 112, 149, 164, 169). Iron sulphate decreases yield (Bull. 236). Bordeaux quite effective as a repellant against flea beetle (Bull. 211). Prepared or hydrated lime found satisfactory (Bull. 98).

New Hampshire.—Late blight common, tipburn common, early blight not serious. Bordeaux pays. O. R. Butler reports ratio of copper sulphate to lime must be about 1: ½ if satisfactory adhesiveness is to be obtained. An 8-4-50 Bordeaux applied every two weeks gave superior protection to a 4-4-50 mixture applied weekly in 1919. (See Pl. Dis. Bull. Suppl. 10, 1920. N. H. Sta. Circular 22, 1920; Phytopath. **4:** 125, 1914 and **9:** 431, 1919, N. H. Bull. 192, 1919 and Circ. 15, 1914, for physical and chemical studies). Bulls. 22, 27, and 45, by H. H. Lamson, dealt with increased yield from spraying.

Vermont.—B. F. Lutman writes that the potato crop in Vermont can be increased 15 to 25 per cent, in the absence of late blight, by keeping the plants covered with Bor-

deaux from early July for two months, necessitating at least four sprayings. Results more pronounced on late than on early potatoes. Bulletin 159 summarizes results of twenty years spraying, begun by L. R. Jones, during which an average of 105 bu. per acre increase was obtained. See also Bulletins 24, 40, and Annual Reports 9, 15, 16, 17, 18. Bulletins 196 and 214 and Potato Magazine, July, 1918, give further data, especially effect on leaves, on tipburn, etc. Advantage of spraying thoroughly established.

Massachusetts.—A. V. Osmun reports that 4-4-50 Bordeaux for early applications, and 5-5-50 for later sprayings give good results in control of late blight. Carefully conducted experiments in potato spraying have not been performed. Bordeaux is recommended to, and commonly used by, growers.

Rhode Island.—Director B. L. Hartwell reports published discussion of Bordeaux for potatoes in Bulletin 38, 1896, and in third Annual Report of Station, 1890, and results of tests given in Bulletin 111, 1906. Bulletin 111 gives a comparison of varieties as to resistance to late blight, and effect on some fifty varieties from spraying five as compared with four times.

Since 1905, various unpublished data have accumulated, which were kindly submitted by Director Hartwell, and are here briefly summarized. In 1906, about seventy-five varieties of potatoes were grown, half the rows sprayed five times with Bordeaux, half with insecticide only. The varieties were classified into two groups, higher yielding and lower yielding; the former averaged 254.7 bu. per acre where sprayed, 160.1 bu. per acre without Bordeaux; the latter 144.1 and 97.3 respectively, Late blight present; but appearance was retarded on sprayed areas, and late varieties in general showed the disease later than did the early varieties. New Queen potatoes also planted at different dates and left unsprayed to see if degree of maturity had any influence in the time of appearance or severity of late blight. Results as follows:

TABLE 2.

Effect of maturity on late blight attacks

DATE OF PLANTING	YIELD ON SEPT. 17	PERCENTAGE OF FOLIAGE ATTACKED BY LATE BLIGHT			
		JULY 31	AUG. 2	AUG. 4	AUG. 9
Apr. 28	188 bu.	10	20	75	90
May 5	153 "	10	20	75	95
" 12	147 "	10	20	70	85
" 19	104 "	3	10	60	85
" 26	91 "	2	5	55	80
June 2	35 "	1	5	50	85

New Queen potatoes sprayed twice with Bordeaux yielded 222 bu. per acre; sprayed four times, 241 and 239 in two plots; not sprayed, 122 and 98 bu. per acre.

In 1907, about seventy-five varieties grown as before, but late blight almost absent. Four sprayings with Bordeaux nevertheless gave 15 per cent increase in yield of potatoes over two ounces. Over six hundred varieties from J. R. Lawrence, East Raynham, Mass., grown without spraying to test resistance to blight; but no progress because of absence of the disease.

In 1908, about four hundred and seventy-five varieties planted on April 29th and 30th, and dates recorded on which leaves had turned brown entirely because of blight. By August 28th, only the varieties, Arabella, Fidelio, Gov. Folk, Prof. Wohltman

Scottish Triumph, Scott's No. 8, No. 10, and No. 43, Table Talk, The Bruce, Violette au Claire, Warrior, and Queen were not entirely brown. Although certain of the varieties yielded over 250 bu. per acre, Table Talk (123 bu.) and Warrior (97 bu.) were the only ones of the above list which yielded over 60 bu. per acre.

In 1909, only about fifty of the varieties were planted, many having been discarded on account of the small yields. An estimate was recorded of the percentage of blight on August 20th. Those varieties then showing less than 10 per cent of blight, together with their total yields of potatoes at harvest time were as follows: Epitomist Bolgiani, 87 bu., Ensign Bagley, 140 bu., Wild Potato from Mexico, 28 bu., Geante Blanche, 165 bu., Junior Pride, 68 bu., Old Hemlock, 78 bu., Pearl of Savoy 61 bu., Pat's Choice, 131 bu., Piqua Chief, 95 bu., Purple King, 30 bu., Richter's Imperator, 19 bu., Rural Blush, 181 bu., Uncle Sam, 85 bu., White Flyer, 209 bu., Whitten's White Mammoth, 168 bu., and Violet, 70 bu. The maximum yields were of McCormack, 303 bu. (15 per cent of blight) and World's Fair, 353 bu. (10 per cent of blight). At least 90 per cent of blight was recorded on August 20th, on the following varieties: Daisy, Merrill, Orguil du Marche, Presbey's 66, Sport of Admiral Foote, and Scotch Rose.

There is no record that the work on selection of blight-resistant varieties was continued later than 1909.

Other observations as follows: in 1906, application of dust Bordeaux, wet, gave a yield of 139 bu. per acre; dust Bordeaux, dry, 165 bu., regular Bordeaux, 234 bu., and without fungicide, 124 bu. In 1914, "Bug Death" applied, 169 bu. per acre, Bordeaux, 175 bu. In 1916, nearly twelve inches of rain in July. With Insecticide and two or three sprayings with Bordeaux, 74 bu. per acre, with Insecticide and about ten applications of Bordeaux, 106 bu. In 1917, Insecticide only, 293 bu. per acre; Insecticide and Bordeaux, 295 bu. per acre. In 1918, Insecticide and two or three applications of Bordeaux, 302 bu. per acre; with Insecticide and about ten sprayings with Bordeaux, 301 bu. per acre. In 1919, blight could not be controlled because of a total of sixteen inches of rain in August and September.

While in certain years no particular increase has occurred, it is evident that the application of Bordeaux in Rhode Island pays with late potatoes because of the danger from late blight and the increase in yield usually resulting from spraying. Many growers believe, however, that spraying is less necessary with the Irish Cobbler type.

Connecticut.—G. P. Clinton has published (Ann. Rep. **1915:** 487, 1916) thirteen years' results in which an average increase from spraying of 38 bu. per acre was obtained in various experiments. Average in blight-free years, 29 bushels increase. Results for 1916 in Ann. Rep. for **1916:** 355–364, 1917; and later results under growers conditions in which less favorable results were obtained are given in bulletin 214, 1919. Clinton reports, "On the whole, farmers in this state have not made a practice of spraying for blight, partly because there are no districts devoted largely to potato growing. Summing up experience for past sixteen years: (1) It certainly does not pay to spray early potatoes. (2) If I were growing late potatoes as a special crop, I would practice spraying, although on the average they do not suffer severely from blight once in five years." Dr. Clinton also considers that spraying might be more advantageous in northern Connecticut. He finds home-made 4-4-50 Bordeaux better than Pickering's solution, or than barium water Bordeaux. Spraying is not likely to become general in Connecticut. In dry years, yield of sprayed fields is sometimes reduced by trampling of vines. Better results from three or four thorough hand sprayings than from power machines going over fields six or seven times. The latter is the more common practice, however.

Quebec.—Late blight common. Bordeaux tested in 1919 in 6 fields in Pontiac County

gave average increases of 60 bu. per acre from 4 sprayings; in 1920, 3 fields sprayed 5 times gave average increases of 150 bu. per acre, and rot was greatly lessened (C. H. Hodge, Agr. Gaz. Can., **7:** 959, 1920). Tests in 60 fields in 40 counties gave an average of 35 per cent greater yield from poisoned Bordeaux than from poison alone in 1919 (G. Maheux, Que. Soc. Prot. Plants Ann. Rep. **12:** 43–46, 1920).

Ontario.—C. A. Zavitz reports (Bull. 239) an average increase of 18.7 bu. per acre from 18 tests during 3 years from spraying the tops and bottoms of the leaves 3 times with Bordeaux. Late blight rot was quite serious 5 years, somewhat troublesome 5 years, and practically absent 16 years during 26 years at Guelph. Bordeaux decreased amount of rot in the crop. Relative resistance of potato varieties to rot given. Prof. J. E. Howitt reports Bordeaux recommended, and progressive growers spray each year with apparently good results even in absence of blight on account of preventing tipburn and increasing or lengthening the growth of the plants. Results obtained at Ottawa by Dominion workers previously mentioned.

New York, Geneva Station.—F. C. Stewart and co-workers have fully demonstrated the value of spraying in New York as a preventive of late blight, and they find spraying pays in the absence of late blight by lessening flea beetle and tipburn injury. Lime sulphur injurious. See bulletins 123, 221, 241, 264, 267, 279, 290, 307, 311, 323, 338, 349, 379, 397, 405, 421. Experiments for ten years at Geneva and Riverhead, and many farmers' tests, gave average increases of from 25 to 97.5 bu. per acre from spraying (Bull. 349).

New York, Cornell Station.—The Extension Department has carried on potato spraying demonstrations in a total of forty-two fields in Allegany, Cortland, Erie, Fulton, Monroe, Nassau, Oneida, Ontario, Otsego, and Steuben counties in 1918 and 1919. For these two years Chupp reports the average yield of the sprayed fields was 240 bu. per acre, of the unsprayed fields 190 bu. per acre. In 1918, no blight occurred; yet an average of twenty-eight fields in seven counties gave an increase of about thirty bushels per acre from applying Bordeaux under growers conditions. In 1920, Bordeaux applied to 57 fields in 11 counties gave an average yield of 277 bu. per acre; the checks yielded 206 bu. per acre. Late blight severe. The Department is also trying the effect of dusting with Sander's copper-lime dust. On the average, as good results were obtained during 1920 in yield and in control of blight as were obtained from Bordeaux sprayed rows.

New Jersey.—Late blight absent 1913 to 1917, present 1918 to 1920; early blight rather serious, tipburn common. H. C. Lint (Ann. Reps. 1915 and 1916) reported good results from Bordeaux. Sulphur dust he found of less value than Bordeaux. M. T. Cook (Circ. 105) reported six year's results in which the effect of Bordeaux on Cobblers and Giants varied. During 1919 and 1920, W. H. Martin performed experiments. Fom his data, the following brief summary is made. In 1919, main crop Cobblers grown in Salem Co. were sprayed five times with a traction sprayer. No late blight, but considerable early blight and tipburn. Plants began to die on July 7th. By July 22nd, an average of 89 per cent of the leaves were dead on the check plots, but only 44 per cent were dead on the 5-5-50 Bordeaux plot, and 27 per cent on the commercial zinc-Bordeaux plot. The latter spray was made up to about the strength of the home-made Bordeaux. Checks sprayed with lead arsenate. Average yield of three Bordeaux plots, 265.4 bu. per acre; of three zinc-Bordeaux plots, 268.6 bu. per acre; of four checks, 216.0 bu. per acre. Increase from spraying in the absence of late blight, about 50 bu. per acre. Late crop Cobblers planted July 1st, on level loam field in Salem Co. were sprayed September 12th, 19th, 29th and October 9th with traction sprayer giving 150 lbs. pressure, three nozzles to row. Check plots unsprayed. Late blight

first observed in check plot Sept. 29th; and by Oct. 9th, 75 per cent of the leaves in the check plots were infected with late blight, while by Oct. 21st, only 3 per cent of the leaves were dead on the sprayed plots. Unsprayed plots ranged from 120.7 to 140.9 bu. per acre, with an average for ten plots of 132.7 bu. per acre; sprayed plots ranged from 172.2 to 196.2 bu. per acre, with an average for nine plots of 183.4 bu. per acre, an increase of about 50 bu. per acre for late crop Cobblers in the presence of late blight. In 1919, main crop American Giants in Monmouth Co. were sprayed four and five times, some at 150 and some at 250 lbs. pressure, with 5-5-50 Bordeaux, the checks being sprayed with lead arsenate. Some early blight and tipburn present. Six check plots gave an average yield of 258.7 bu. per acre; three interspersed Bordeaux plots sprayed four times gave an average of 239.4 bu. per acre, an average loss of 19.3 bu. per acre from spraying. In another series, three plots sprayed five times with Bordeaux at 150 lbs. pressure gave an average yield of 215.2 bu. per acre; six corresponding checks, an average of 269.9 bu. per acre, a loss of 54.7 bu. per acre from spraying. Three plots sprayed five times at 250 lbs. pressure gave an average yield of 226.2 bu. per acre; six corresponding checks averaging 255.6 bu. per acre, a loss of 29.4 bu. per acre from the use of Bordeaux on American Giants. No late blight on the Giants. In 1920, Giant variety (main crop) in Middlesex Co., sprayed six times with 5-5-50 Bordeaux applied with three nozzles per row at 150 lbs. pressure gave an average yield of 246.6 bu. per acre; lead arsenate checks yielded 261.7 bu per acre. Late crop Giants in Salem Co. similarly sprayed with Bordeaux five times yielded 178.0 bu. per acre; unsprayed check 150.4. Late blight present: on October 18th, 62 per cent of leaves dead on check plots, 10 per cent on sprayed plots. Main crops Cobblers in Salem Co. sprayed five times gave yield of 281.8 bu. per acre with 5-5-50 Bordeaux, 226.0 bu. per acre with 4-4-50, and 260.3 bu. per acre on lead arsenate check. No late blight. Late crop Cobblers in Salem Co. sprayed five times yielded 199.3 bu. per acre; unsprayed check 163.9 bu. per acre, arsenate of lead check 175.2 bu. per acre. On October 18th, 92.5 per cent of the leaves dead on check, 9.0 per cent on 5-5-50 Bordeaux plot, 68.0 per cent on arsenate of lead plot. Most of this dying from early blight and tipburn, though considerable late blight was present.

It evidently pays to spray Cobblers in New Jersey, but not Giants, except in the case of the late crop which may suffer from late blight. Actual decrease in yield from spraying main crop Giants.

Pennsylvania.—C. R. Orton has helped greatly with the cooperative spraying project, supplying many ideas, and with E. L. Nixon through the Extension Service of the Pennsylvania State College has obtained a mass of data as to the value of spraying in Pennsylvania. Late blight sometimes present, early blight and tipburn rather serious. Remarkable increases from Bordeaux even in absence of late blight (See Pot. Mag., Jan., 1920). In 1918, thirty-two demonstrations of spraying were held in twelve counties, a total of 314 acres being sprayed an average of five times at an average cost of $8.65 per acre, and resulted in an average increase of 34.8 bu. per acre. In 1919, 224 demonstrations were held in twenty-three counties, spraying a total of 1,787 acres an average of 5 times with an average increase of 42.9 bu. per acre, worth in 1919 $58.50, at a cost of $9.00 per acre. In 1920, spraying was carried on on 318 farms in forty-two counties on a total of 6,193 acres with an average increase of 74.7 bushels per acre obtained.

In 1919, the project as previously outlined was performed in two places. At State College, the average of the plots sprayed six times with Bordeaux and insecticide was 152.6 bu. per acre; those sprayed with insecticide only 122.5 bu. per acre, a gain of 30 bu. per acre. Early blight was unusually severe, tipburn present but not severe

until about September 1st, late blight became epidemic and destroyed about 50 per cent of the plants in unsprayed plots. Later applications of Bordeaux more valuable than earlier because of occurrence of late blight. At State College, another field was sprayed four times when it was thought to be advantageous to the plants, on July 18th and August 5th, and 27th and September 9th. Late blight also serious on unsprayed plants. The sprayed plots yielded 309 bu. per acre; the unsprayed 229, or 80 bushels per acre increase from spraying. Heath's Late Beauty variety was used in both cases. At Girard, the experiment was also performed in 1919, using the Petoskey variety. Late blight practically absent. Average yield of plots sprayed seven times, 123.3 bushels; of those receiving only insecticide, 100.5 bu. per acre. Low yields because of badly sprouted seed. The middle to late season sprayings were found to be better when late blight was absent than late season spraying only.

Five applications of 4-4-50 Bordeaux, using pressure of 200 pounds and 100 or 125 gallons per acre, using two or three nozzles per row, gives protection against late blight in Pennsylvania and remarkable increases in yield whether late blight is present or absent.

Delaware.—T. F. Manns reports late blight not often serious. In 1912, 1913, and 1914, not reported; 1915, 1 per cent in northern part; 1916, little damage; 1917, 2 per cent of late potatoes affected; 1918, ½ of 1 per cent; 1919, 2 to 5 per cent of late potatoes affected. In 1920, late blight very severe; average of 10 to 20 per cent rot. F. D. Chester reported (5th Ann. Rep., 1892) co-operative spraying. In one case, yield was 96 pounds per row where sprayed 4 times; 92 pounds where unsprayed. Some blight present. Another plot yielded 101 pounds per row where sprayed 4 times; 84 pounds where unsprayed. No other data available.

Maryland.—J. B. S. Norton reported in 1906 (Bull. 108) that 3 years' tests showed an average increase in yield of 52 per cent from spraying 3 or 4 times from June to September.

Virginia.—Director T. C. Johnson and L. B. Smith of the Truck Experiment Station report that late blight rarely does any damage in eastern Virginia; but early blight and tipburn are common. Late blight occasional in western Virginia. Results of work show that profit was obtained by using Bordeaux as a carrier for arsenicals. (Bulls. 14, 17, 28). Bulletin 29, and Potato Magazine, Aug. 1919, report results showing that nicotine sulphate, fish-oil soap, and water kill more aphids than Bordeaux, arsenate and nicotine; but the latter combination gave an average of more than 25 bu. per acre increase in yield over the former. Bordeaux and arsenate gave about the same yield as the nicotine and soap, although Bordeaux does not affect aphids particularly. L. B. Smith reports Bordeaux effective for early blight in 1920.

West Virginia.—N. J. Giddings has published (Ann. Rep., 1909–10 Bull. 165) results of spraying tests. The results of spraying on a commercial scale, in years when very little early or late blight appeared, are as follows:

TABLE 3.

Results of Spraying Potatoes in West Virginia

YEARS	LOCATION OF PLOTS	AV. YIELD, SPR. PLOTS	AV. YIELD, UNSPR. PLOTS	INC. FROM SPR. BU.	INC. FROM SPR. PER CENT
1909, '12, '13	Morgantown	87.2 bu.	70.5 bu.	16.7	23.7
1911, 1912	Moundsville	78.1 "	69.4 "	8.7	12.6
1910	Reedsville	82.3 "	59.1 "	23.2	39.3

Lime sulphur reduced yields. In 1919, Professor Giddings sprayed Carman No. 3 with 5-5-50 Bordeaux, at an altitude of over 3,000 feet, using one acre spray plots and

one-half acre check plots, and obtained a 50 per cent increase in yield. Favorable results from spraying were secured also in 1920.

North Carolina.—R. W. Leiby has tested poisoned Bordeaux and Bordeaux without poison, with hand-picking the beetles, and with no spraying whatever. (Ext. Circs. 48, 103; Bull. N. C. Dept. Agr. 254). For the late crop in western N. C., an average for 6 years gave an increase of 52 bu. per acre from poisoned Bordeaux over check without Bordeaux or poison. Four similar tests in eastern N. C. gave an increase of 26 bu. per acre. Five years' results gave an average increase of 16.6 bu. per acre from poisoned Bordeaux as contrasted with Bordeaux alone.

South Carolina.—Director H. W. Barre reports late blight quite prevalent in Charleston and Beaufort Counties in 1920. Some spraying tests, but no figures as to effect on yield. Late blight seldom occurs.

Georgia.—H. P. Stuckey and B. B. Higgins (Bull. 123) reported for 1915 an average yield of 66 bu. per acre where sprayed twice with 4-5-50 Bordeaux mixture, and an average of 49.5 bu. per acre without Bordeaux. Increase in yield also reported in 1916. Late blight absent; but early blight common on unsprayed plots. No other data at present from Georgia.

Florida.—C. D. Sherbakoff reports late blight in 1912, 1917, 1918, and 1919. In 1919, the blight caused a loss of 50 per cent in the Hastings district. Cooperative experiment in 1919 with grower, leaving 3 distributed strips unsprayed, each 4 rows wide and 200 feet long, in each of two test fields of 20 acres. Results as follows:

Field 1. 20 acres new ground, sprayed 5 times beginning when plants were 8–10 inches high. Field planted on January 25th and 26th, 1919.

Field 2. 20 acre tiled field, planted on Feb. 7th and 8th, 1919, sprayed 7 times begining when plants were 5–6 inches high. Average yields were as follows:

Sprayed	rows, field	1,	160.3	lbs.	No.	1	potatoes;	total	225.7 lbs.
Unspr'd	" "	1,	115.3	"	"	1	"	"	184.7 "
Sprayed	" "	2,	258.3	"	"	1	"	"	327.7 "
Unspr'd	" "	2,	170.3	"	"	1	"	"	243.3 "

The above figures are for 2 rows, and are the average of the 3 counts in each case. Average increase in yield where sprayed, 29 per cent, and 45 per cent increase in No. 1 potatoes. Average yield of field No. 1, 31 barrels per acre; field No. 2, 43 barrels per acre. Cost of spraying the 40 acres, about $286; increased yield worth $2,210. Further data in Florida Grower 20, No. 1, 1919. Probably would pay to spray each year in Florida; though results when late blight is absent not yet determined.

Ohio.—A. D. Selby reports potato spraying not commonly practised, because Ohio has late blight less than 40 per cent of the seasons. Spraying pays when late blight occurs. Value to growers of applying Bordeaux each year not definitely known.

Indiana.—H. S. Jackson reports late blight rare or absent; early blight not serious; tipburn serious. F. C. Gaylord wrote in 1918 that very few growers used Bordeaux; but those who did considered that it paid. No results of experimental tests available

Illinois.—G. P. Clinton reported (Bull. 40, 1895) some increase from spraying potatoes with Bordeaux and poison. J. Pieper writes that farmers who have made comparisons feel that there is considerable advantage in the use of Bordeaux. No definite figures.

Michigan.—G. H. Coons writes that Michigan potato spraying must give protection against early blight, hopper burn and late blight. Of these early blight is probably least important, and hopper burn, because it is present nearly every year, is probably the greatest loss producer, Late blight so far as available records show has been

present in epidemic form in 1885, 1896, 1900, 1902. 1903, 1905, 1912, 1915, 1920. Since 1911, it can definitely be stated that hopper-burn has reduced the potato crop 25 per cent in the case of late potatoes and 50 per cent in the case of early potatoes, working along with drought to depress the average yield per acre for the state in some seasons as low as 60 bushels.

A questionnaire to leading potato dealers, county agents, and potato growers showed that potato spraying was not at all generally practiced, some of the counties growing large acreages of potatoes reporting that spraying for diseases was not practiced at all.

Evidence as to value of spraying is not available for any consecutive period. The college has carried on many demonstrations since 1890; but results of these are not available. C. A. McCue (Bull. 236) obtained in 1905, a year when late blight was a factor, increases of 28 to 40 bu. per acre from 4-4-40 Bordeaux applied 4 to 14 times, and an increase of 11.5 bu. per acre from lime alone applied 14 times. He also reported large increases in yield from certain farmers' trials.

In 1912, H. I. Eustace (Circ. 15) published the results of spraying tests made in several preceding seasons, reporting that spraying paid during the absence of blight. In 1911, an increase of 39 bu. per acre was obtained from 4 applications of Bordeaux.

For twenty years, Hon. Jason Woodman, a progressive farmer in southwestern Michigan, has sprayed potatoes as part of the farm practice. These tests with land well adapted to potatoes and heavily fertilized have given the best results yet obtained in influencing yields. Mr. Woodman reports an average gain of the sprayed over the check every year with one exception, and in this year, the spraying was done with commercial Bordeaux. The average gain from spraying for the period is put between 75 and 100 bu. per acre.

FIG. 1. A CONSPICUOUS EXAMPLE OF THE EFFECT OF BORDEAUX, CENTER TWO ROWS UNSPRAYED. Photographed in 1915 near Kalamazoo, Mich., by C. W. Ward. By courtesy of G. H. Coons.

In 1915, spraying tests by farmers near Kalamazoo, Michigan, gave increases in yield of 130 to 166 bu. per acre from 5 sprayings.

G. H. Coons (Spec. Bull. 85, 1918) advises spraying every year for those growing potatoes intensively, and everyone should spray, if July is cold and wet.

Wisconsin.—Spraying often necessary because of late blight. J. G. Milward and R. E. Vaughan report favorable results from spraying even in the absence of late blight. from increased foliage growth and protection against flea-beetle and leaf hopper damage. Potato spraying on increase among progressive growers, and better machines are being introduced. R. D. Rands (Wis. Res. Bull. 42, 1917) reported an average of slightly over 10 per cent increase in yield for early varieties, and from 10 to 43 per cent increase in yield for late varieties from the use of Bordeaux in the absence of late blight. Early blight was profitably controlled by spraying.

Minnesota.—Late blight not uncommon; early blight and tipburn (principally hopper burn) common. G. R. Bisby and A. G. Tolaas have summarized (Bull. 192) the results. The average increase for 14 years at St. Paul was over 31 bu. per acre for late varieties, and about 27 bu. per acre for early varieties. Experiments elsewhere in the state also demonstrate that the application of 5-5-50 Bordeaux pays even in the absence of late blight. Weaker Bordeaux found less valuable. Some indication of better yield succeeding year from tubers produced under sprayed vines.

Iowa.—Late blight not common. A. T. Erwin, bulletin 171, 1917, reported five years' result of spraying against tipburn and early blight. Marketable potatoes yield as follows, average 5 years: 3 applications 5-5-50 Bordeaux, 114.3 bu. per acre; 5 applications, 120.9 bu.; 7 applications, 121.5 bu.; check, 103.9 bu. Cost figured at $0.96 per application per acre. Five applications most profitable. The Departments of Entomology and Plant Pathology cooperated in 1920 in experiments with Bordeaux 4-4-50 plus black leaf 40, one pint per 100 gallons of mixture, and report fair control of tipburn. In one field, average 0.14 nymphs of leaf hopper per leaf where sprayed, and 0.50 where unsprayed. Many nymphs killed.

Missouri.—J. T. Rosa, Jr., reports that spraying has not been practiced by growers for the control of diseases. No data as to the effect on yield. Early blight not ordinarily serious, tipburn the main limiting factor in growing potatoes in this section during the summer season. Late blight practically absent.

Manitoba, Saskatchewan, Alberta.—Late blight absent because of dry atmosphere, early blight and tipburn uncommon. Experiments with Bordeaux not yet tried. In areas in Manitoba and Saskatchewan, and around Edmonton, Alberta, the Colorado beetle is rare or absent, so that even insect sprays are not applied. Flea beetle quite common, aphids often abundant late in the season, leaf hoppers not serious.

North Dakota.—No late blight. Early blight and tipburn not serious. H. O. Werner found (Bull. 129) increased yield to result from Bordeaux.

South Dakota.—Late blight rare, early blight and tipburn common. Manley Champlin reported Bordeaux mixture little used. Materials are difficult to obtain throughout the state. In 1918, tests at Brookings gave yield of 96.7 bu. per acre sprayed with Bordeaux, and 78.3 bu. per acre without Bordeaux for Early Ohios, and 67.5 and 84.2 bu. per acre respectively for "Bugless." Reasons for inconsistent yields uncertain. No other data available.

Nebraska.—G. L. Peltier reports no data as to the results of spraying. Early blight and tipburn present.

Kansas.—L. E. Melchers performed spraying experiments during 1918, 1919, and 1920. The results are important, for, in Kansas, late blight does not occur; but early blight, tipburn, and hot weather cut down the yield. Melchers' figures cannot be given in full here. In 1918, a half acre plot planted to northern grown seed was sprayed by H. H. Haymaker with 2-3-50, 3-4-50, and 4-5-50 Bordeaux plus lead arsenate, four or three applications. Average yields per row were as follows:

	2-3-50	3-4-50	4-5-50
Irish Cobbler	28.75 lbs.	31.42 lbs.	30.17 lbs.
Corresponding check	27.12 "	31.75 "	38.00 "
Early Ohio	31.42 "	35.42 "	39.25 "
Corresponding check	30.37 "	37.75 "	35.25 "

In 1919, a similar experiment was performed. The results from various strengths of Bordeaux and various schedules are as follows:

Variety	Treatment	Av. yield per row	Inc. in yield per row	
			lbs.	per cent.
Irish Cobbler	checks	85.00		
Irish Cobbler	sprayed	89.25	4.25	5.00
Early Ohio	checks	69.66		
Early Ohio	sprayed	72.50	2.84	4.00

The 4-5-50 Bordeaux gave the best results, the 3-4-50 next best, and the 2-3-50 the poorest results.

In 1920, the experiment was carried on in a ten acre field of the best known grower in the Kaw Valley. Early blight and tipburn almost absent, a rare condition in Kansas. The average yield of sprayed Early Ohios was 281.4 bu. per acre; unsprayed, 280.9; of Irish Cobbler: sprayed, 282.0; unsprayed, 303.0.

Under Kansas conditions, the three seasons' evidence indicates that Bordeaux mixture exerts little influence on the yield.

Kentucky.—W. D. Valleau reports tests at Lexington in 1920 with two sprayings in the spring, which resulted in about ⅓ increase in yield. Late blight rare; early blight slight; tipburn common.

Tennessee.—S. M. Bain published bulletins (Vol. **8**[1], Vol. **15**[2]) dealing with fungicides, but no data as to the effect of Bordeaux on potatoes.

Alabama.—G. L. Peltier reports that potato spraying experiments have not been performed. Early blight and tipburn often present.

Mississippi.—D. C. Neal reports that late blight has not been found. Early blight common and spraying would probably pay, but no data available.

Louisiana.—C. W. Edgerton reports that late blight has been found, but that conditions are not suitable for its general development. Early blight and tipburn not ordinarily serious. Value of Bordeaux unknown.

Texas.—J. J. Taubenhaus reports late blight absent; early blight and tipburn present. Tipburn worse on plants from potatoes injured by frost in transit to Texas. Potatoes grown as an early crop. No definite figures as to the effect of spraying.

Oklahoma.—No experimental data found as to the effect of spraying potatoes with Bordeaux mixture.

Arkansas.—J. A. Elliot reports late blight rare, early blight not very serious, tipburn rather serious. Bordeaux used in 1920, but no effect on yield. Different number of applications also gave little difference.

Montana.—Late blight absent; early blight and tip-burn not serious. D. B. Swingle reports no data as to the effect of Bordeaux on yield.

Wyoming.—A. F. Vass reports no publications on this subject.

Colorado.—H. G. MacMillan reports tipburn and early blight slight; late blight absent. No data as to the effect of Bordeaux.

New Mexico.—F. C. Werkinthin wrote in 1918 that late blight does not occur, and early blight is not common. L. H. Leonian wrote in 1920 that no data had yet been obtained as to the effect of using Bordeaux.

Arizona.—J. G. Brown reports early blight reduced yield 30 per cent in 1919, and 5 per cent in 1920, in northern Arizona. Bordeaux has been used successfully for early blight, but no figures available.

Utah.—B. L. Richards states that tipburn is serious. Early and late blight do not cause damage. Value of Bordeaux unknown.

Nevada.—C. W. Lantz reports Nevada not troubled with diseases which make spraying necessary. No data as to effect of Bordeaux.

Idaho.—C. W. Hungerford reports late blight absent; early blight and tipburn not serious. Growers do not use Bordeaux. No data as to its effect on yield.

British Columbia.—W. Newton reported (Agr. Gaz. Can., **2:** 334, 1915) increases in yield of from 5 to 58 bu. per acre from spraying 3 and 5 times with a 4-4-40 (4-4-50 U. S. gallon) Bordeaux. This was during an unusually dry season when late blight was not very prevalent. French (Brit. Col. Circ. 10) reports that late and early blights do little damage in dry portions of British Columbia. J. W. Eastham has other data, received too late to include here.

Washington.—F. D. Heald reports Bordeaux used to a limited extent in the Puget Sound region where late blight occasionally occurs. Foliage troubles of potato rare in the Yakima Valley. Tests there in 1918 as follows:

No spraying, average of two tests, 255.5 lbs.
3-3-50 Bordeaux once, average two tests, 189.0 lbs.
3-3-50 Bordeaux twice, average two tests, 238.0 lbs.

No value from spraying in this experiment, where leaf diseases were absent. No other data at present available.

Oregon.—M. B. McKay reports early blight and tipburn slight, late blight about once in ten years west of Cascade Mountains, quite serious in 1920. No data as to effect of Bordeaux in Oregon.

California.—Tests began with copper-lime sprays in 1886 (See Exp. Sta. Rec. **41:** 405, 1919). J. T. Barrett reports early blight sometimes rather destructive especially to the second crop; but no data as to the value of Bordeaux on potatoes in southern California.

U. S. Department of Agriculture.—Much early work was done in testing and introducing Bordeaux after its discovery in France (see Lodeman, E. G., The spraying of plants, New York, 1913, for a summary of this work). L. A. Hawkins published, in 1912, a bulletin on "Some factors influencing the efficiency of Bordeaux mixture." (Bur. Pl. Ind., Bull. 265.) F. C. Cook of the Insecticide and Fungicide Laboratory has been testing lime-water and barium-water sprays (U. S. Dept. Agr., Bull. 866) and found them effective on potatoes. He also reports tests (Jour. Agr. Res. **20:** 623–636, 1921) indicating that the percentages of solids and of nitrogen is higher in tubers from sprayed vines than in tubers from unsprayed vines; but found no indication that tubers from sprayed vines produced sprouts with a composition or rate of growth different from sprouts from tubers from unsprayed vines.

SUMMARY AND CONCLUSION

Bordeaux is necessary to control late blight in the Maritime Provinces, in Quebec, in northern New England, and in New York. Increased yields are general in the absence of late blight. Late blight, is less common in Ontario, Rhode Island, Connecticut, New Jersey, Delaware,

Pennsylvania, Ohio, Michigan, Wisconsin, Minnesota, and Florida. Careful spraying each year, nevertheless, pays in Pennsylvania, and evidently also in Ontario, Michigan, Wisconsin, and Minnesota. Spraying Cobblers in New Jersey has been found to pay; but main crop Giants may be reduced in yield from Bordeaux. In Rhode Island and Connecticut, the late crop is in general benefited from spraying. Late blight occasionally occurs in certain other eastern and central states, and Bordeaux appears valuable in Maryland, Virginia, West Virginia, North Carolina, Georgia and perhaps Kentucky, although further experiments are needed in certain of these states. Spraying is, of course, valuable in any region in years in which late blight is serious. Bordeaux has been found valuable in Iowa and under certain conditions in North Dakota and British Columbia. Bordeaux did not exert much influence in Kansas during 3 years nor in Arkansas in 1920. The value of Bordeaux is uncertain over most of the rest of North America.

Copper dust appears valuable, as indicated by the Canada and New York reports. Burgundy mixture was found scarcely equal to Bordeaux in Canada. Work on the resistance of potato varieties to late blight has been performed in Rhode Island, Canada, and elsewhere: see Wm. Stuart, Vermont Sta. bulletins 115, 1905; 122, 1906; and 179, 1914, and L. R. Jones, U. S. Dept. Agri., Bur. Pl. Ind. Bulletin 87, 1905, and Jones, Giddings and Lutman U. S. Dept. Agr., Bur. Pl. Ind., Bulletin 245, 1912. Data on the chemical, physical, and biological effects of Bordeaux have been published by workers in New Hampshire, Vermont, U. S. Dept. Agr., Canada; see also Martin, Jour. Agr. Res. **7**: 529–548, 1916, Duggar and Bonns, Ann. Mo. Bot. Gard. **5**: 153–176 and Ritzema Bos, abstract in Bot. Abs. **3**: 235, 1920. Data from Virginia, Iowa, Maine, Wisconsin, and Canada refer to the use of various compounds with Bordeaux to kill insects.

It is evident from this summary that our knowledge of the value of Bordeaux mixture on potatoes is still very incomplete. Tests of Bordeaux and other compounds are needed in many parts of North America in order to determine their value under various conditions. There is excellent opportunity for cooperative spraying work with entomologists. The best fungicide to apply, its effect on the potato plant, and the optimum schedule for spraying potatoes, need further study. Many workers will desire to compare spraying and dusting. Questions of scientific interest as well as practical importance await experimentation. The results obtained will naturally be published by the workers; but the writer will gladly act in any capacity he can in correlating or bringing together miscellaneous information relative to the use of Bordeaux mixture and other fungicides on potatoes.

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THE UNIVERSITY OF MINNESOTA
Agricultural Experiment Station

RELATION OF MOSAIC TO RUNNING-OUT OF POTATOES IN MINNESOTA

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RELATION OF MOSAIC TO RUNNING-OUT OF POTATOES IN MINNESOTA

By F. A. Krantz and G. R. Bisby[1] [2]

INTRODUCTION

"Running-out," in Minnesota as elsewhere, is a serious factor in potato production, hence it has seemed advisable to present a brief statement of certain experiments which have been performed to determine something of its nature and the way in which it is transmitted. It should be understood at the outset that running-out is used here in the sense of the degeneration of seed stocks rather than the degeneration of varieties. The term is in common use among growers in this sense when it is used in connection with decreased yield associated with certain plant types.

EARLY HISTORY OF RUNNING-OUT IN MINNESOTA

For thirty-seven years the Minnesota Agricultural Experiment Station has given some attention to the degeneration of potato seed stock. The earlier statements (27, 28) contained meager descriptions of run-out plants. Very little was known at that time about the nature or the cause of the trouble, it being simply noted that "degeneration," "loss of stamina," or "loss of vigor," resulted in smaller yields.

In 1886 Porter (27) reported that four seasons' results led to the conclusion "that change in climate, soil, and season will not restore the lost stamina of the older varieties . . . and that the quality and productiveness of even recently introduced popular varieties are rapidly deteriorating. . . . At present the cause of this deterioration seems to be due to the loss of constitutional vigor in the plant due to long continued propagation from the same stock, in which all the diseases and defects of years of cultivation have accumulated."

Green (5, 6, 7) in 1889, 1895, and 1896 called attention to the fact that it was impossible to maintain seed stocks at University Farm, while seed stocks of the same varieties in other sections of the state seemed to maintain themselves indefinitely. The comparative difference between the size, uniformity, and yield of plants of run-out seed stock and those of newly introduced seed stock was brought out by Kohler

[1] Resigned March, 1921.

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(15) in 1909. The measurements and yields reported indicate the dwarf nature and decreased yield of plants from old seed stock. Photographs on file indicate that Kohler was dealing with mosaic dwarf. (See Figs. 1, 2, 4.) He further noted that the disorder was not a general phenomenon affecting all plants of the old seed stock alike, but that there was marked variability in size of the individual plants as compared to the uniformity in size of plants from new seed stock.

Fig. 1. Mosaic Dwarf Plants of Irish Cobbler Variety
Healthy row on left, diseased row on right. Photo. by A. R. Kohler, July 30, 1908.

In 1914 Orton (26) described the symptoms of mosaic, curly dwarf, leaf roll, and related diseases. In his discussion on the occurrence and distribution of curly dwarf, he mentions that this disease probably "plays a large role in the deterioration of potatoes." Stakman and Tolaas (32), in 1916, called the attention of growers to the presence of these diseases in Minnesota. In 1917 Wellington (35) pointed out the similarity of the symptoms exhibited by "run-out" plants at University Farm and those of curly dwarf as described by Orton. Curly dwarf was described by Orton as a disease distinct from mosaic and it has been generally so considered until recently. Observations and experiments carried on in Minnesota have led the writers to conclude that much, if not all, of the so-called "curly dwarf" in Minnesota, as probably elsewhere, has been nothing more than an extreme case of mosaic. This does not mean there may not be cases of curly dwarf not due to mosaic, but it appears that in Minnesota at least the greater part of what has been known as "curly dwarf" was merely severe

cases of mosaic. The term "mosaic dwarf" has been used to designate such extreme cases of mosaic and to distinguish them from any non-infectious curly dwarf.[3]

EARLY HISTORY OF POTATO MOSAIC

A review of the older literature on degeneration of potatoes indicates that mosaic is probably not a new disease. A condition spoken of as "curl" was observed in England before the 18th century. The early descriptions of curl strongly suggest that most of it was very probably the same disease which is known today as mosaic dwarf, altho leaf roll and other diseases may also have been present.

Fig. 2. Mosaic Dwarf Plants

Healthy plant and mosaic dwarf plant of the Green Mountain variety planted Jan. 2, 1920. Photo April 1, 1920.

Three affected rows of Early Ohio between two rows of healthy Green Mountain stock. Photo. July 10, 1918, shown on cover.

Arthur Young (40), under date of July 26, 1782 (published in 1784), reported certain varieties to be curled, others not. Curl was even then apparently not considered a new disease. Young (41) also reported observations on the disease made in 1784. Thomas Martyn's (21) edition of Philip Miller's "Gardeners' and Botanists' Dictionary" also reports that certain varieties were preferred or neglected as early as 1784 because of the presence or absence of curl in them, quoting Marshall as authority for these statements. Marshall (23), in 1788,

[3] The recent report by Murphy (Canada Dept. Agr. Div. Bot. Bul. 44, 1921) on crinkle and leaf-drop, received after this bulletin was in print, refers to conditions similar to some of those found at University Farm. The authors have recognized, in the descriptions of symptoms occurring at University Farm, that crinkling of the leaves may occur and that the lower leaves may drop. There are, however, also marked symptoms of mosaic present which are particularly evident when the plants are grown in the greenhouse. The whole complex is transmitted as outlined herein and it is considered that the general diagnosis of mosaic dwarf is not erroneous, altho subsequent work may show that mosaic dwarf at University Farm may be resolved into more than one disease as indicated by the symptoms occurring.

wrote as follows regarding potatoes in Yorkshire, England: "There is some reason to believe that the disease, which has of late years been fatal to the potato crop in this and other districts, under the name of *Curled Tops* has arisen from too long a continuance of declining varieties. Be this as it may, it appears to be an opinion established here, by some years' experience, that fresh varieties raised from seed, are not liable to that disease." He cites one instance in which "its removal was in all probability owing to the introduction of new varieties."

He writes further that "the district under survey furnishes a remarkable instance respecting this disease. The Morelands are at present in a manner free from it, while the Vale is still in some degree infected with it. Plants procured from the Morelands remain free from it in the Vale, the first year; but being continued, become liable to the disease."

"The disease of curled tops is seldom obvious at the first coming up of the plants; but attacks them as they increase in size; the entire top becoming dwarfed and shriveled as if affected by drought, or loaded with insects; they nevertheless live, and increase, though slowly, in size, but the roots are unproductive."

"Where the attack has been partial, *weeding out the diseased plants* as they failed, is said to have had a good effect. And, *it is said,* the Morelanders got rid of the disease through this means."

Marshall's statements are not unlike those found in the literature up to a few years ago. The observations on the Morelands and the Vale parallel our own experience at University Farm.

Mordaunt (24) in 1790, gave some idea of the symptoms, stating that "The plant is subject to a disease which often reduces the produce above one half; the farmers very aptly call it the curl, the leaves curling to a very great degree; when that happens you find only one or two small roots (tubers) not worth the expense of taking up; this happens sometimes to a fourth of the field, or more, to the farmers' great detriment." He considered the "real cause" to be a milliped which bored into the stems, whereas Hollins (8), in 1791, suggested that curl was occasioned by earthing up the plants. A writer signing himself "Howdeniensis" (9) wrote under date of October 16, 1804, that "The curl has only been known about forty years, and may be attributed solely to differences in temperature" in pits ("pies") and in the field. He reported that sets from the north of Scotland produced few curled plants.

Cathcart (3) writes as follows: "That destructive and continuous disease, the curl, says Mr. Rahn, an exact authority, was first noticed in this same year, 1764. Partial though the affectation of the curl may have appeared, it yet broke out in the same form in widely separated

countries. Stephens, (Book of the Farm) the most practical writer I know, characterizes the curl as weakness. The leaves curl and crumple; when virulent they shrivel. The tubers are small and rot; the herbaceous stems are puny; and a small insect feeds on the stem; some call this the cause; a few plants curl one year; planted the next, half the crop will prove diseased; the disease is hereditary."

The statement that the disease known as curl was known as far back as 1764, and the published records found back to 1782, suggest

Fig. 3. Inoculated and Uninoculated Plants

Plants A and B are from separate halves of the same tuber, planted January 2, 1920. A was inoculated on February 25 with plant juice taken from plant shown at right in Fig. 2. Photo. April 1, 1920.

that the curl probably occurred at least from the time potatoes became a common source of food in the British Isles. While Banks (2) considered that the potato was introduced into the United Kingdom first in 1586, it was not, according to Miller, (22) "till some time after the middle of the 18th century that the potato came to be generally used as an esculent root through the greater part of England." Miller's Dictionary of 1771 lists only two varieties of potatoes, "white and red," but does not mention "curl." In a paper given in 1807, Knight (12) reported that he considered correct the idea that the "duration of a variety, in a state of perfection," was only about fourteen years. He associated the "running-out" of varieties with curl disease, the symptoms of which he described in papers (13-14) published in 1818. Various other reports on curl were published during the first half of the 19th century. On the continent, Höse (10), 1804, mentions leaf curl and says that the yield was upheld by rogueing all affected plants.

None of the other reports found by the writers added anything new to the ideas already presented. Late blight came into the British Isles probably between 1830 and 1840 (11), and immediately caused serious losses. Some writers, as Thompson (34), apparently confused curl and late blight, but the literature on potato diseases after 1840 for the most part clearly referred to late blight, altho curl undoubtedly persisted as a more or less important trouble in England and elsewhere.

SYMPTOMS OF MOSAIC

The symptoms of mosaic, particularly as found in Minnesota, are as follows: The leaves of affected plants are commonly characterized by a mottling due to the presence of light and dark green areas distributed so as to give the well-known mosaic appearance. The mottling occurs on any part of the leaf and the individual light or dark green areas vary greatly in size and shape. All gradations in intensity of mottling can be found, and often, especially later in the season, these symptoms may not be evident. The leaf symptoms may or may not be accompanied by a dwarfed or stunted condition of the plant. In more severe cases, where dwarfing is common, the leaves are practically always curled and crinkled in a manner typical of this disease. The curling is usually downward toward the under surface, and the curled leaves usually turn brown and dry much earlier than leaves of healthy or less severely affected plants. In fact, the lower part of the plant is often entirely defoliated in severe cases of mosaic dwarf in Minnesota. Potato plants affected with mosaic yield much less than healthy plants. The tubers are both smaller and fewer in number, the yield being reduced in some plants to a few small tubers. The decrease in yield is usually in direct proportion to the severity of the symptoms as manifested by the parts of the plant above ground.

Leaf roll also has been observed in Minnesota, but it apparently is not serious and should not be confused with mosaic. In contrast to mosaic the lower leaves of plants affected with leaf roll usually curl upward along the midrib. This upward rolling or curling may be decidedly pronounced or very inconspicuous. Affected leaves are rigid, crisp, and brittle, breaking easily when bent between the fingers. As far as is known, leaf roll plays only a subordinate part in the running-out of potatoes in Minnesota.

Fig. 4. Same Plants as Shown in Figure 3, Fourteen Days Later, April 15, 1920

CAUSE OF MOSAIC

Potato mosaic is caused by what is known as "filterable virus." Diseases of this kind may often be spread from plant to plant by the injection of the sap of a diseased plant into the tissues of a healthy one. However, no living organism large enough to be seen even with the aid of the most powerful microscope, can be detected in such plant sap or virus. The passage of the virus through the finest porcelain filter will not affect its virulence, hence the term "filterable virus."

Tobacco mosaic was the first disease of this kind to be studied extensively. It was shown by Mayer (18), director of the experiment station at Wageningen, Holland, as early as 1886, that the disease was communicable by artificial inoculation with the sap of diseased plants. Mayer did not thoroly understand the nature of the disease, however, because he attributed it to bacteria which he could not isolate. It remained for the more exhaustive work of Woods (38), Clinton (4), and Allard (1) to demonstrate clearly the nature of the cause.

Since tobacco and the potato are closely related, it was not unreasonable to suppose that "mosaic" and "curly dwarf" of the potato were similar in nature to mosaic of tobacco [Melchers (19), Murphy (25),

Orton (26), and Wortley (39)]. This was not clearly shown, however, until 1919, when Schultz, Folsom, Hildebrandt, and Hawkins (30) and Schultz and Folsom (31) published the results of their extensive investigations. Among other things they showed that potato mosaic can be transmitted by transferring juice from a diseased to a healthy plant, and that at least two species of aphids can transmit the disease whether they are transferred artificially or are dispersed naturally. It was also demonstrated that grafting a healthy cion on a diseased stock or a diseased cion on a healthy stock resulted in an infection of the original healthy cion or stock. They also verified the fact which had been previously demonstrated by Orton (26), Wortley (39), Stewart (33), Melhus (20), and Murphy (25), that the disease is readily carried over in the tubers from affected plants.

The data presented in this bulletin on mosaic dwarf verify to a large extent the work of Schultz and his collaborators on mosaic, and furnish evidence that mosaic dwarf has been largely responsible for the running-out of seed stocks in Minnesota. Experiments are also described which indicate the possibility of a practical means of controlling the disease.

PRELIMINARY EXPERIMENTS WITH MOSAIC DWARF

Preliminary experiments to determine something of the nature of the disorder which was causing seed stocks to run out were begun by Kohler in 1911. As reported by Wellington (35) these experiments indicated that the disorder was quite markedly affected by environmental conditions. In 1914 a series of experiments outlined by Wellington was begun that was designed to ascertain the part played by environmental factors in the spread and development of the disease. These tests were expanded in subsequent years. Several of these experiments, which have a direct bearing on the transmission of mosaic dwarf, will be referred to later in this report.

PERPETUATION OF MOSAIC DWARF THROUGH SEED TUBERS

The perpetuation of mosaic disease in potatoes by means of the seed tuber has been observed repeatedly. Hill selection work at University Farm in 1913, 1914, and 1915 furnished additional evidence that mosaic dwarf is carried over from year to year in the tubers from diseased plants. In observations made on 3,614 hills of Early Ohio and 3,098 of Rural New Yorker, no cases were noted in which the tubers from diseased plants produced healthy hills. On the other hand, tubers from a large number of supposedly healthy plants produced diseased plants. By the third season all the progeny from the original selections produced only diseased plants. It was apparent that infection

from diseased to healthy plants had taken place, and that after a plant had become infected it transmitted the disease through its tubers to its progeny.

Fig. 5. Plants Grown from Two Halves of Same Tuber

A diseased cion was grafted on plant at left. The graft was unsuccessful. The effect produced by the sap of the diseased plant coming in contact with the cut tissue of the healthy plant is shown. Photo. seven weeks after attempted graft, April 15, 1921.

TRANSMISSION OF MOSAIC DWARF FROM PLANT TO PLANT

BY INOCULATION

Schultz, Folsom, Hildebrandt, and Hawkins (30), and Schultz and Folsom (31) were able, by a transfer of the plant juice, to transmit mosaic disease of potatoes from diseased to healthy plants. As the symptoms exhibited in the deterioration of seed stocks at University Farm usually more nearly approached the characteristics designated as mosaic dwarf, and as this disease has sometimes been referred to as physiological, it was deemed advisable to repeat these experiments in order to ascertain with certainty whether this running-out at University Farm could be considered as belonging to the same category as running-out elsewhere.

Plants of the Green Mountain variety were grown in boxes 14 inches square and 14 inches deep. Each of six tubers planted was divided into two pieces, and each piece was planted in a separate box. Of the resulting plants, growing in separate boxes, that from one half of each tuber was held as a control. This plan was followed in all the experiments performed in the greenhouse.

Inoculation was effected by bruising the stems and leaves and rubbing into them the unfiltered plant juice of diseased plants. The plants

were free of insects at all times, and no fumigation was necessary. The seed pieces were planted January 8, 1920, and the plants inoculated February 25. In each of the six potatoes treated the inoculated plants produced mosaic dwarf foliage and the uninoculated plants remained healthy.

The plants were observed daily in this experiment, and thirty-three days elapsed before symptoms of the disease could be detected with certainty. The greenhouse temperature during this period ranged between 62 degrees F. at night and 66 to 70 during the day. A distinct mottling developed on the new foliage; the leaves became corrugated, owing to the shortening of fibro-vascular tissue which later caused them to become considerably curled while the stem remained dwarfed. (See Figs. 3 and 4.) The foliage that had developed before inoculation or immediately after, appeared normal until from 10 to 15 days after mosaic symptoms had been noted on the terminal leaves, when the lower leaves began to wither and dry and finally fell from the plant.

BY GRAFTING

Studies were made with another series of plants of Green Mountain variety on the transmission of the disease by grafting diseased cions on healthy stock and healthy cions on diseased stock. The cleft graft was used and gave very satisfactory results. The diseased cions infected the healthy stock and new leaves or shoots arising from them showed symptoms of disease similar to that of the diseased cion. Infection occurred even when the graft was unsuccessful. (See Fig. 5.) Similarly, when healthy cions were grafted on diseased stalks the new growth on the cions showed symptoms of mosaic.

When half-tubers from diseased plants and half-tubers from healthy plants were grafted together, the disease was transmitted to the plant which grew from the healthy half-tubers. A union similar to that between cion and stalk occurs between the two united half-tubers. All eyes on the diseased half-tuber of the graft were removed to insure that all stalks should grow from the healthy one. The condition of plants from the grafted half-tubers was checked with that of the plant from the control half-tubers, which were planted separately. The tubers were grafted and placed in sand thirty days before planting. The plants appeared above ground seven days after planting. Those from the healthy part of the grafted half-tubers appeared healthy the first week, while the plant from the diseased control half-tuber showed indications of mosaic. The second week the disease could be detected on the plants from the healthy half of the grafted tubers, and two weeks later they exhibited a typical mosaic dwarf condition. (See Fig. 6.) The plant from the healthy control half-tuber remained healthy throughout.

The observation made on the transmission of the disease by grafting confirmed the conclusions arrived at in the transmission of the disease by transferrence of plant juices, i.e., that the disease is transmitted from diseased to healthy plants through the plant juices, the symptoms appearing on the foliage of the new shoots.

Fig. 6. Transmission of Disease Through Tuber Grafting

Plant at left from healthy half tuber. Plant at right from diseased half tuber. Plant in center from graft of remaining halves of each. Plants are from healthy half, as eyes were removed from diseased half. Photo. June 8, 1920.

The infectious character of potato mosaic and the ability to transmit it to the tomato were demonstrated by grafting a healthy cion of the tomato on a diseased potato stalk. (See Fig. 7.) The tomato cion became diseased, whereas the parent plant remained healthy. The symptoms, however, were not altogether similar to those commonly found in tomato mosaic. The relationship of mosaic diseases of members of the *Solanaceae* is further supported by observations in the field in 1919. Wild nightshade (*Solanum nigrum*) plants growing in a field with mosaic tomato plants became affected with mosaic; all those found elsewhere appeared to be healthy.

THROUGH THE SOIL

In the studies on the transmission of mosaic dwarf, infection never was observed except after the juice from a diseased plant was transferred to a healthy plant. Close proximity of diseased and healthy seed pieces in the soil had no effect on the plants grown from the healthy seed pieces. This condition was obtained in the experiments on the transmission of the disease by tuber grafting. In those cases where the cells of diseased and healthy half-tubers failed to unite,

the plant arising from the healthy half-tubers remained free of the disease tho it was in physical contact with the diseased half-tuber. The following experiment further indicates that the disease is probably not transmitted through the soil from diseased to healthy plants during

Fig. 7. Healthy Tomato Cion Grafted on Mosaic Dwarf Potato Stock
Note mottled condition of leaves. Photo. May 18, 1920.

the growing season. Healthy and diseased plants were grown in the boxes (14 inches square and 14 inches deep) shown in Figures 8 and 9. The plants were grown in the greenhouse and were free of insects at all times. The roots of the diseased and healthy plants in the same box intermingled and in the later stage of growth the foliage of the two plants came in contact. The healthy plants remained normal throughout their growth and showed no symptoms of infection. A test of the progeny of the healthy plants in the field gave all normal and healthy plants, free of the disease.

BY HARBORING IN THE SOIL

After it became evident that apparently the virus of mosaic dwarf was not diffusing through the soil, two experiments were begun to determine whether the virus could live in the soil. Halves of the healthy tubers were planted in boxes in soil in which diseased plants previously had grown. When the diseased plants were harvested no effort was

made to remove the roots from the soil. The control half-tubers were grown in steam-sterilized soil and boxes. The second experiment was identical with the first except that the haulm of the diseased plant was buried in the soil in which it had grown before planting the healthy half-tubers. The control half-tubers were again grown as in the previous experiment. All these plants remained apparently free of the

Fig. 8. Testing Transmission of Disease Through Soil
Plant on left healthy; plant on right diseased. Photo. February 23, 1920.

Fig. 9. Difference in Growth Between Healthy and Diseased Plants
Plants in box on left are the same as in Fig. 8. No evidence of transmission through the soil was obtained. Photo. April 23, 1920.

disease during their growth period, but since the progeny of these experiments have not yet been tested, it can not be stated with certainty that no infection occurred.

SPREAD OF MOSAIC DWARF IN THE FIELD

EFFECT OF EXCLUDING INSECTS

Since 1917 an experiment has been in progress to determine the effect of insect cages on preventing the spread of mosaic dwarf. The seed stock used in this experiment was obtained from the North Central Experiment Station, Grand Rapids, Minnesota. Each year stock was obtained from Grand Rapids from the same original stock and used as a check in the experiment. Healthy plants of the Green Mountain variety and in the succeeding year their progeny were enclosed with a cheese-cloth covering from July 5 to the time of harvesting, each year for four successive seasons. The cheese-cloth was supported on a wooden frame 4 feet high, 12 feet wide, and 36 feet long. (See Fig. 10.) The progeny of the plants enclosed by cheese-cloth and of those

Fig. 10. Cheese-Cloth Cages for Enclosing Plants
These cages were used from 1917 to 1920, inclusive. Photo. Aug. 7, 1920.

grown in the open were tested in the open in comparison with healthy seed stock. The results for three seasons are shown in Figure 11.

It will be noted that the productivity of the seed stock of the plants from which insects were excluded was in each of the three years equal to the check, while the productivity of the same seed stock when grown in the open for one year dropped thirty-three bushels below that of

the check. Practically no potatoes were produced the second year. The rapid decline in yield of the plants grown in the open is further shown by the yield of the enclosed seed stock after growing in the open one season. In 1919 another cage similar to that shown at the top in Figure 10, except that the north side was left open, was placed beside the completely enclosed cage. Both cages were placed over the plants on the same date and covered plants of the same rows. In 1920 the progeny of the plants grown under the partially enclosed cage contained 20.4 per cent of plants affected with mosaic dwarf, while the progeny of the plants grown under the completely enclosed cage, were wholly free from the disease.

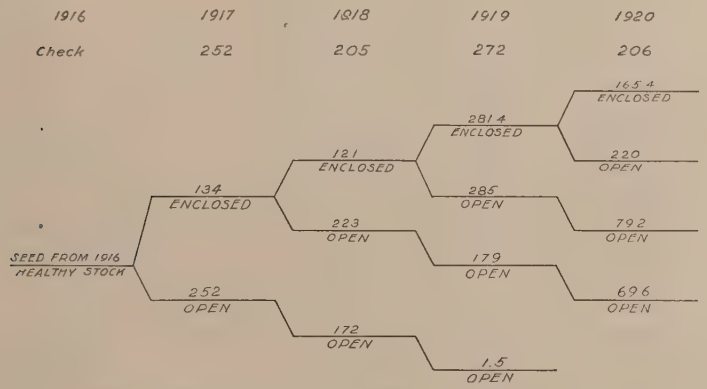

Fig. 11. Effect on Yield of Progeny, of Excluding Insects by Method Shown in Fig. 10

The fact that the plants and their progeny from which insects were excluded were free from mosaic dwarf while adjacent plants grown in the open were quickly affected, supports the evidence obtained in the greenhouse that mosaic dwarf probably does not spread from diseased to healthy plants through the soil. The disease was evidently spread by means of aphids or other insects which had not become common on the plants before July 5, and which subsequently did not have a chance to carry the infection to the plants under the cheese-cloth cages.

DISTANCE OF SPREAD

Two separate experiments, performed in 1918 and 1919, illustrate the spread of mosaic dwarf in the field at University Farm. A lot of seed was obtained in the spring of 1918 from Dr. G. H. Coons, of Michigan. Part of this lot was planted near other plots on which mosaic dwarf plants were grown. Another part was planted in an isolated place where no potatoes from diseased stock were being grown within twenty-five rods. The progenies of these two lots were brought

Fig. 12. Effect of Isolation on Spread of Mosaic Dwarf

Two rows at right were grown from seed stock which was grown among infected plants in 1918. Two rows at left were from the same original stock but grown in an isolated plot in 1919. Photo. July, 1919.

together in 1919. The two rows at the right in Figure 12 were planted from the plot growing adjacent to diseased plants in 1918, and the two rows at the left in the same figure were planted from the isolated plots. The yield from the seed tubers of plants grown adjacent to diseased plants in 1918 was less than one half of the yield from seed tubers grown in an isolated plot in 1918 (15½ pounds and 33 pounds respectively or 62 and 135 bushels per acre). (See Fig. 13.)

Similar results were obtained in the spring of 1918 in a second experiment with a disease-free lot of Green Mountain potatoes obtained from the substation at Grand Rapids. The progeny of the plants grown in 1918 in an isolated plot at University Farm yielded 203.5 bushels per acre in 1919, while the progeny of the same stock grown in 1918 in a row which was adjacent to a diseased row yielded 67 bushels per acre. In both instances the soil had never before grown potatoes. This indicates, as do other results given, that healthy stock at University Farm becomes infected with mosaic dwarf from diseased neighboring plants grown from infected seed stock.

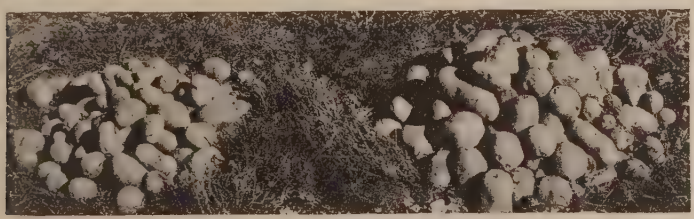

Fig. 13. Effect of Isolated Seed Plot on Yield

Tubers at left were from seed stock of plants grown among infected plants in 1918. Those at right were from the same stock grown in an isolated seed plot in 1918. Photo. 1919.

The spread of mosaic dwarf from a diseased row to adjacent healthy rows is illustrated by an experiment, the results of which are given in Table I. The rows were 3 feet apart and were 4 rods long. The position of the rows in the field in 1918 is also shown in Table I. In 1919 the progenies were grown under comparable conditions in the same plot but not adjacent to each other.

TABLE I

INFLUENCE OF DISTANCE FROM DISEASED PLANTS ON AMOUNT OF INFECTION AS INDICATED BY YIELD

Position of rows 1918	Condition of seed stock 1917	Bushels per acre 1918	Bushels per acre 1919
1. Green Mountain	Healthy	150.4	232.8
2. Rural New Yorker	Healthy	139.4	158.6
3. Irish Cobbler	Healthy	174.2	41.7
4. Rural New Yorker	Mosaic dwarf	12.8	.....
5. Green Mountain	Healthy	172.3	66.9

The yield for 1918 shows that infection of healthy stock from diseased neighboring plants occurs too late to have a noticeable effect on the yield in the same season. The yield for 1919 indicates the amount of infection that occurred in 1918. It will be noted that the rows which were adjacent to the diseased row in 1918 had become very severely infected as shown by their decreased yield in 1919; while the third row, nine feet from the diseased row in 1918, gave but a slightly decreased yield in 1919.

INFLUENCE OF ENVIRONMENT

It has generally been thought that loss of vigor in varieties of potatoes could be restored by growing the seed stock for several years in a more favorable environment. Macoun (17) reports that seed stock of potato varieties which had declined in vigor at Ottawa, Ontario, were restored to their original productiveness after having been grown several years under the more favorable conditions at the Canadian substations. Very similar results were obtained from some studies on the rejuvenation of seed stock which were carried on coöperatively in Minnesota by the Central station, at St. Paul, and the substations at Duluth, Grand Rapids, and Crookston. The interchange of seed stock has been practiced since 1914. The results of six years' work are illustrated in Figures 14 to 18 inclusive. The influence of seasonal conditions on the yield of potatoes during the progress of the experiment has tended somewhat to obscure the results. The actual yield of rows 4 rods long calculated to bushels per acre, is given. Corrections for fluctuations in yield due to seasonal variations were not made.

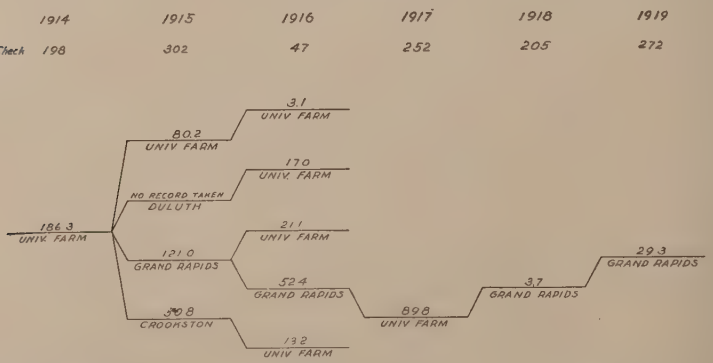

Fig. 14. Effect of Environment on Spread of Mosaic Dwarf as Indicated by Yield of Gold Coin Potatoes

Note the decline in yield of progeny of stock grown at University Farm, and lack of decline of progeny of stock grown at Grand Rapids. Yield at University Farm of healthy Green Mountain stock renewed each year given as check.

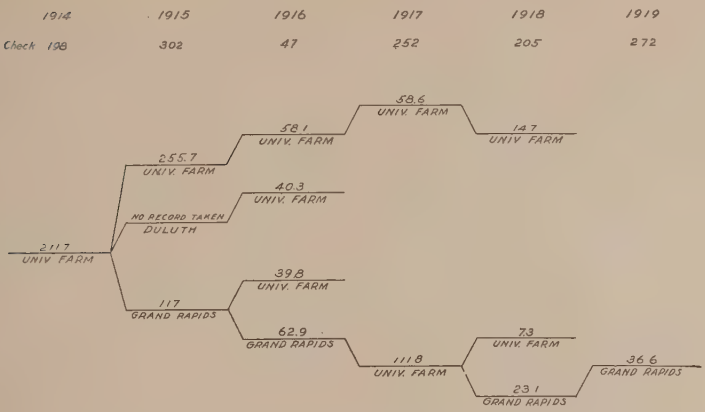

Fig. 15. Effect of Environment on Spread of Mosaic Dwarf as Indicated by Yield of Peerless Junior Potatoes

Note decline in yield of progeny of stock grown at University Farm and lack of decline of progeny of stock grown at Grand Rapids. Yield at University Farm of healthy Green Mountain stock renewed each year given as check.

A comparison with the actual yield of check rows, at University Farm, will indicate sufficiently the favorableness or unfavorableness of the season. A careful survey of the diagrams will show that after partially diseased lots were transferred to the substations, there was usually no further decline in yield. In some instances there was a gradual increase in yield each year while the variety was grown at the substations, as can be noted in certain lots of Minnesota No. 2 (see Fig. 17) and of Burbank (see Fig. 18).

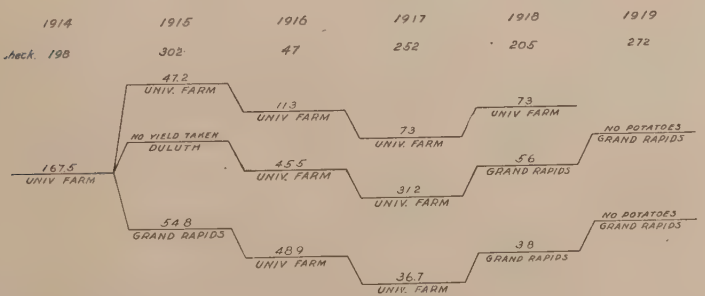

Fig. 16. Effect of Environment on Spread of Mosaic Dwarf as Indicated by Yield of Early Ohio Potatoes

Note failure of badly diseased stock to reproduce itself at Grand Rapids. Yield at University Farm of healthy Green Mountain stock renewed each year given as check.

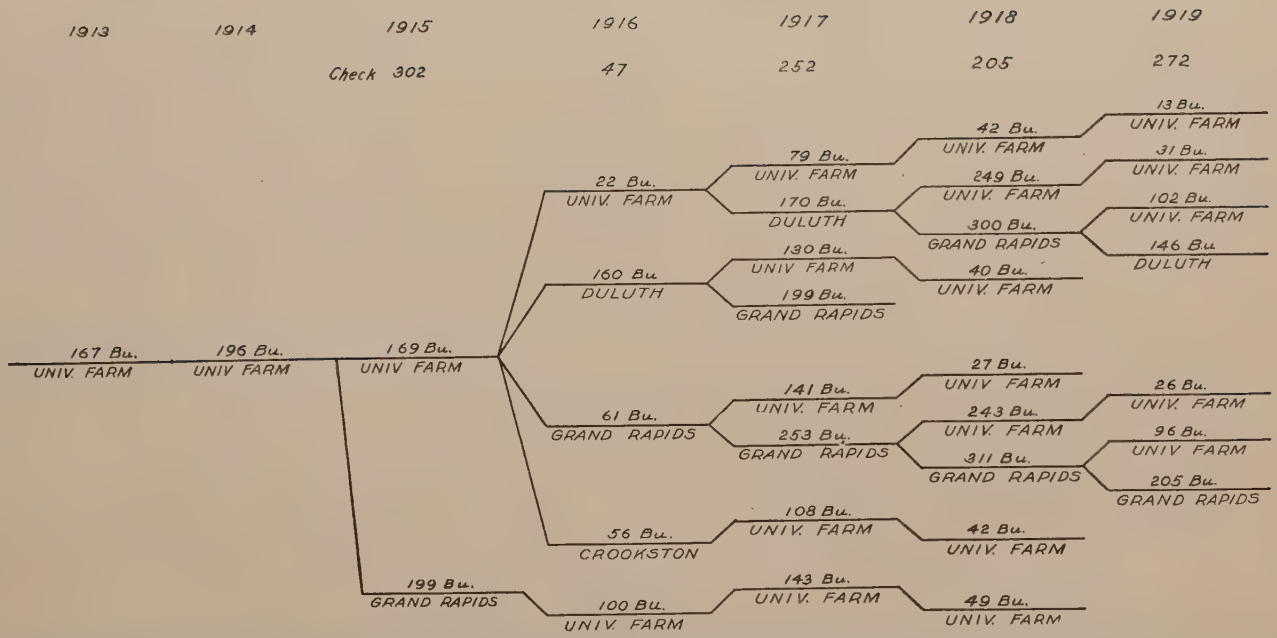

Fig. 17. Effect of Environment on Spread of Mosaic Dwarf as Indicated by Yield of Minnesota No. 2 Potatoes

Note continuous decline in yield of progeny of stock grown at University Farm, and increased yield of progeny of stock grown at Duluth, Grand Rapids, and Crookston. Yield at University Farm of healthy Green Mountain stock renewed each year given as check.

In order to ascertain whether the progeny of diseased plants actually were free from mosaic, severely affected lots of some of the stock were grown at Grand Rapids in 1918 and 1919. The results show the behavior of mosaic dwarf plants in a region where growth conditions for the potato plant are more favorable than at University Farm.

TABLE II

YIELD PER ACRE OF HEALTHY AND DISEASED STOCK AT GRAND RAPIDS

Lot	Variety	Bushels per acre 1918	1919
1	Green Mountain (healthy stock)	510	491
2	Gold Coin (mosaic dwarf)	4	29
3	Peerless Junior (mosaic dwarf)	23	37
4	Burbank (mosaic dwarf)	15	17
5	Burbank (mosaic dwarf)	16	42
6	Burbank (mosaic dwarf)	8	11
7	Early Ohio (mosaic dwarf)	11	0
8	Early Ohio (mosaic dwarf)	6	0
9	Early Ohio (mosaic dwarf)	4	0

	1914	1915	1916	1917	1918	1919
Check	198	302	47	252	205	272

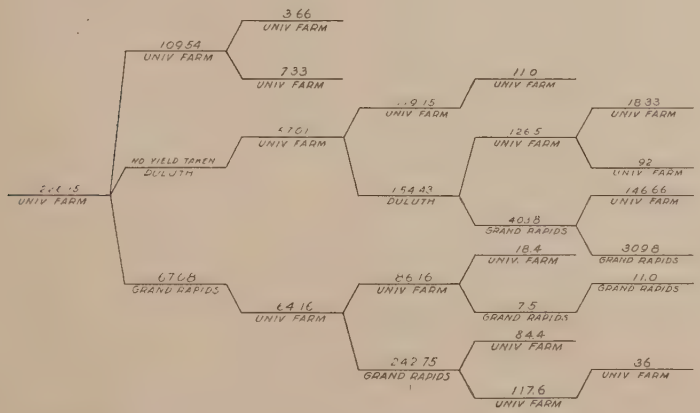

Fig. 18. Effect of Environment on Spread of Mosaic Dwarf as Indicated by Yield of Burbank Potatoes

Note continuous decline in yield of progeny of stock grown at University Farm and increase in yield of progeny of stock grown at Duluth and at Grand Rapids. Yield at University Farm of healthy Green Mountain stock renewed each year given as check.

A few of the diseased lots yielded a little more the second season, while from other diseased lots no crop was secured. The slight increase in yield in some of the lots can not be regarded as significant, as the highest yield was less than ten per cent of a normal crop, as is indicated

by checks, and no tubers of marketable size were produced. Observations made on the plants in the field in both seasons also showed that no noticeable improvement was taking place. The seasons of 1918 and 1919 were very favorable to the growth of potatoes at Grand Rapids, as is shown by the checks. The behavior of the diseased plants in this experiment seems to indicate that the improvement in previous years probably was not caused by actual rejuvenation of the diseased plants, but more likely through their elimination, either by their failure to produce tubers, or by producing tubers of such small size that they were naturally discarded in saving seed stock. Altho a similar elimination of the progeny of mosaic dwarf plants occurred at University Farm, the development of the disease and its spread to healthy plants was apparently so rapid as to prevent its elimination in this manner.

ABSENCE OF IMMUNITY TO MOSAIC DWARF VARIETIES

The possibility of securing varieties resistant to mosaic dwarf is receiving considerable attention from investigators. The records of the performance of varieties grown at University Farm indicate that there is but slight possibility of finding a disease-resistant variety. Porter (27), in 1886, reported that 325 American and 40 European varieties were being tested. In the following year Porter (28) again reported that 370 varieties of potatoes, embracing all that were of value in this country and in Europe, were being tested. In both years the rapid decline in vigor of varieties is commented upon. Green (5), in 1889, stated that it was impossible to maintain most varieties of potatoes. Over 150 varieties are reported to have been discarded at this time. The weakness in vigor of European varieties is especially mentioned. Since these were imported directly from Europe during the four years from 1883 to 1886, inclusive, it is probable that mosaic disease was introduced at that time. In 1895 Green (6) made the following statement: "Repeated experiments made on a large scale and with many kinds show that all varieties of potatoes rapidly deteriorate in yield, size of tubers, and vigor, when planted continuously at University Farm."

Since 1895, 325 named varieties, embracing 681 separate seed lots, have been grown. The performance record of these varieties shows that when once the varietal stock became affected, as indicated by a decline from the normal yield, it required at the most but two or three years for the stock to deteriorate completely. Lists of varieties purporting to show relative degrees of susceptibility to mosaic are to be found in the literature. At University Farm certain varieties have

maintained their productivity longer than others. There was, however, a greater difference in this respect between seed stocks of the same variety than between varieties themselves. As all seed stocks become infected sooner or later, the difference in length of time required for this infection to occur quite evidently depended on the proximity of plants to diseased plants and did not necessarily indicate any difference in inherent resistance between seed stocks.

STRAINS

Selection of seed stock was the first method employed in trying to prevent the running-out. In 1896 Green (7) reported that with the utmost care in saving potato seed stock grown at University Farm the yield would begin to decline after the second or third year. Kohler (15), in 1909, stated that selection of tubers for planting from the general stock was not sufficient to maintain a high-yielding strain. From 1909 to 1913 mass-tuber and hill selection were undertaken with a large number of varieties. The hills in the field were selected for vigor and freedom from disease, while small, abnormal, and diseased tubers were eliminated by bin selection. This selection had no appreciable effect in retarding the decline in productiveness of varieties. Under the conditions which prevailed at University Farm, where mosaic dwarf was prevalent to such a degree that two or three years was long enough to cause complete deterioration of the seed stock, this method of mass-hill and mass-tuber selection would have proved the most efficient method of isolating a disease-resistant strain in a variety, if such a strain existed. Later, in 1914, 1915, and 1916, individual hill selection was practiced on quite an extensive scale with Rural New Yorker and Early Ohio. The result of this work has been reported in a paper by Wellington (36) in which he points out the uselessness of hill selection under conditions where rapid degeneration or running-out is prevalent. Selection was practiced for more than twenty years in order to maintain the yield of seed stocks, and all the important commercial varieties grown in this country were included. The failure to isolate a resistant strain during this period suggests that if such strains exist within varieties, they probably are not very numerous.

PREVENTION OF MOSAIC

The experimental evidence already given suggests a practical method for the control of mosaic disease. As there was no apparent spread of the disease from diseased plants to healthy plants through the soil, and as no infection could be detected on healthy plants when grown in soil containing diseased tubers, roots, and haulms of diseased plants,

it would seem that the spread of virus occurs between the above-ground parts of the plant. In the greenhouse the disease did not spread from diseased to healthy plants even when the foliage of these plants came in contact. These facts would lead us to conclude that insects were probably the sole means by which the disease is spread. The results of four years' work in protecting plants by the use of insect-proof cages show that the insects that act as carriers do not make their appearance in any number before July 5. This would apparently exclude insects with biting mouth parts, such as the Colorado potato beetle and the potato flea beetle, which are quite prevalent before July 5, but would include the sucking insects, such as plant lice and leaf-hoppers, which apparently were not present in the fields until some time after July 5. Rogueing out all diseased plants in a seed plot, thereby eliminating the virus, would probably be as effective a method for protecting healthy seed stock as excluding the insect carriers from healthy plants by means of insect-proof cages. As the symptoms of mosaic may not appear on all varieties in certain regions, it would be advisable to rogue out all weak plants as well as those that were noticeably affected with the disease. It would further seem desirable to have the seed plot separated from the general field in order to lessen the danger of infection from this source.

SUMMARY

I. Probably the most important factor in the running-out of potatoes in Minnesota is the mosaic disease. The term "mosaic dwarf" has been used to designate the more severe symptoms of mosaic. Much, if not all, of the so-called curly dwarf in Minnesota probably is caused by mosaic.

II. Mosaic is apparently not a new disease of potatoes. The condition "curl" frequently discussed in the older literature, probably for the most part referred to what is known today as mosaic.

III. Mosaic was probably introduced into this country through the importation of varieties. This seems to have been the case at University Farm.

IV. Mosaic dwarf is perpetuated from year to year by planting tubers from diseased plants. It can be transmitted artificially by transferring the juice of diseased plants to healthy plants, by grafting a portion of a diseased plant on a healthy plant, and by grafting a diseased tuber on a healthy tuber.

V. The virus did not spread through the soil when healthy and diseased plants were grown side by side in the same box and their roots allowed to intermingle. Field experiments with insect cages further indicate that infection does not occur through the soil. Healthy plants

did not become infected when in soil which previously grew diseased plants, even when the soil contained the refuse of the diseased plants.

VI. Infection of healthy plants in the field has been prevented by excluding from the plants insects which appear later than July 5. Healthy plants grown in plots some distance from diseased plants did not become infected.

VII. Environmental conditions have a considerable influence on the spread and development of mosaic in Minnesota.

VIII. During the last thirty-four years all named varieties of any commercial importance found in the United States and a large number of foreign varieties have been tested. No varieties have been found to be immune from mosaic dwarf. Selections failed to isolate resistant strains within varieties.

IX. It may be possible to control mosaic by growing disease-free seed stock in a plot isolated from possible sources of infection. The disease may be eliminated by growing an isolated seed plot in which all diseased plants are rogued out before sucking insects appear on the plants.

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Other Hosts.

Field observations show that this insect may live temporarily on many hosts among which are: bean, apple, beet, rhubarb, raspberry, red clover, Swiss chard, strawberry, cucumber, lettuce, dahlia, hollyhock, elm, box-elder, burdock, rose, etc.

On some of the above the leaf-hopper merely feeds, but on beet, apple, beans and box-elder it will also reproduce.

Life History.

The potato leafhopper (*E. Mali*) lives over winter in the adult stage in protected places such as among thickly growing weeds, in brush, etc. In June they come out from their resting place and feed for ten days or so on the apple and other trees and shrubs, and at this time females predominate. At the end of the feeding period they migrate to potatoes and beans and begin mating and egg laying.

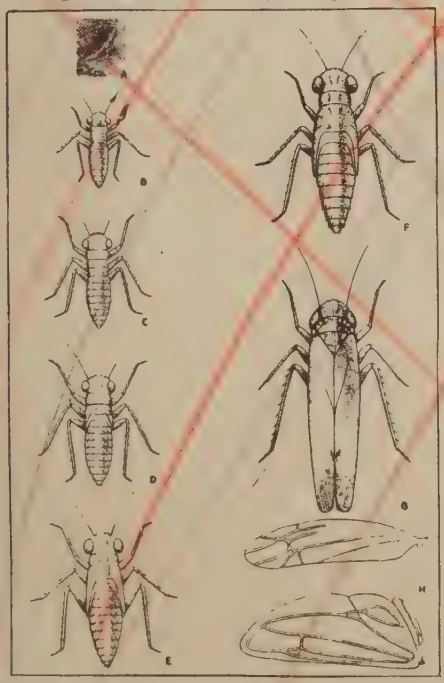

PLATE 2.—The potao leafhopper.

A. Egg in leaf tissue; B. First nymphal stage; C. Second stage; D. Third stage; E. Fourth stage; F. Fifth stage; G. Adult stage; H. Outer (elytron) and inner wing, showing venation. After Bull, 334, Wisconsin University Agr. Exp. Sta.

The eggs are about 1/30 of an inch long and are transparent at first. They are deposited in the petiole and midribs of leaves where they change from transparent white to yellow. In from ten days to two weeks the eggs hatch and the young nymphs appear as whitish, wingless hoppers. They begin to feed at once and as they absorb the plant juice they grow and become green. They shed the skin five times during their growing season and become winged adults in about seventeen days. When quite young they are to be found mostly on the lower side of the leaves and they move about but little.

The adult females have a long egg laying period and nymphs in all stages may be found up to the time of the first frost.

The first generation of the season causes the first noticed hopperburn on the potatoes. Adult females of this generation give rise to a second generation during the season and usually the severest attack of hopperburn occurs at the period when adults of the first generation and nymphs of the second generation are feeding at the same time. The over-wintering leaf hoppers are members of the second generation.

Varietal Susceptibility.

In Quebec the Irish Cobbler appears to be more susceptible to leafhopper-burn than Green Mountain. Unfortunately the writer does not happen to have at the present moment facts relative to susceptibility for other potato growing areas of Canada. In Wisconsin Early Triumph is affected worst and Rural New Yorker least. An important point to notice is that early planted potatoes are liable to suffer more from hopperburn than late planted varieties. It is also significant that plants from seed of diseased vines always suffer more severely than plants from seed of healthy vines.

Control.

Spraying with Bordeaux 4-4-50 is effective in controlling hopperburn provided that the underside of the leaves is sprayed thoroughly. This is obvious when considering the fact that nymphs feed on the underside of leaves as above noted.

Stem-Rot of Sunflowers in Manitoba

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Professor of Botany, Manitoba Agricultural College.

The cultivated sunflower (*Helianthus annuus*) is coming to hold a very important place as a silage crop in Western Canada and in other regions where corn does not thrive. Rust sometimes defoliates sunflowers to some extent, and other leaf diseases may cause slight reduction in the forage value of the crop; but in general, the plant is considered fairly free from disease. During 1920 and 1921, however, the disease mentioned below assumed considerable importance in Manitoba.

This disease may be called "stem-rot" or "wilt", as either name expresses a conspicuous symptom. "Crown-rot" would be very appropriate for the most common early appearance of the disease; but often, much more than the crown is affected and sometimes the crown itself may be normal while some upper portion of the plant is attacked. Since the name "wilt" as applied to plant diseases so commonly implies a clogging of the vascular tissue without external rot, it would seem that "stem-rot" is as applicable as any common name for this disease.

Figure 1.—Shows wilting of the plants in the field, August 10th, 1921.

The same or a similar disease of cultivated sunflowers was reported in 1912 by Lawrence (6) from the state of Washington, and attributed by him to a new species of Sclerotinia, *S. perplexa*. The disease apparently received little attention subsequently until 1920, when it was reported as common in Montana (7), Manitoba (1), Ontario (4), Oregon and Washington (8). It was also found in Minnesota for the first time (8). Morris and Swingle (7) consider the fungus to correspond closely to *Sclerotinia libertiana* Fcl., which is known to attack a large number of hosts, particularly vegetables. Brodrick found *S. libertiana* in 1919 on parsnips in Manitoba (2), specimens being sent to Dr. G. H. Coons who made the determination. It has also been reported on carrots (3, 9). The writer found Sclerotinia on both parsnips (see fig. 2) and carrots at Winnipeg in the fall of 1920, resembling the fungus found on sunflower, and inoculations showed that the fungus isolated from sunflower would attack carrots and parsnips. Jagger (5) has recently described a new species of Sclerotinia which is characterized by smaller sclerotia than are produced by *S. libertiana*. The writer has not definitely determined the species of Sclerotinia causing the sunflower disease in Manitoba, but can at least agree with Morris and Swingle as to its resemblance to *S. libertiana*. Conidia such as Lawrence described were not found in cultures of the fungus, although microconidia are to be found.

The disease has been found in Manitoba

at the Agricultural College, at Charleswood, at Clandeboye, at Brandon by Mr. I. L. Conners and at Morden by Miss Margaret Newton. No extensive survey of the province for this disease has been made.

A good opportunity was provided during 1920 and 1921 to study this disease in a field of about 20 acres at the Agricultural College, since the same field was planted to sunflowers both years. This field was near the Red River and had been principally covered with brush. The field was broken and sown to oats in 1919, then to sunflowers in 1920 and 1921. These were the first cultivated crops, except in one small area in the field (where the disease was worst) on which a farmhouse had once stood. The soil in this area contained much humus.

The stem rot was first found in 1920 on August 1st, It was found to be present in 1921 on July 17th. The plants found injured had all developed to 4 or 6 or more feet in height. Temperature or other factors seem to preclude attack upon seedlings or very young plants. The disease usually attacks the plants at or near the surface of the ground, and passes up and down, sometimes reaching two or more feet above ground under our conditions. Occasionally, cases are found where the organism has attacked the plant one, two, or more feet above ground, the stem being healthy below. The affected area is at first slightly sunken and black, but the colour fades to a brown and finally to a yellow. Mycelium of the fungus is usually abundant, outside and within the stem; although under dry conditions, it may not be evident on the exterior above the ground. This mycelium becomes aggregated into sclerotia which are white at first, then black outside and white within. The mycelium spreads abundantly through or on the surface of the soil, and may be seen conspicuously present under leaves, or where moist conditions prevail. The plants wilt soon after attack by the fungus (Fig. 1) and the stems are easily broken at the injured area; as the disease progresses, the stem becomes shredded from the "retting" of the tissue, leaving strands of fibro-vascular bundles. Eventually the sunflower plant is killed, and dries out, thus checking the growth of the fungus, and hard sclerotia of various shapes and sizes are found abundantly within the stem, especially in the area previously occupied by the pith, and clasping the stem on the outside.

The disease occurred especially in patches in the field, as noted above, in which often practically every plant in a square rod or more was killed. Here and there, through the sunflower field, however, one or a few plants in a place would be found affected. The composite weeds, *Iva xanthifolia* and Canada Thistle (*Cirsium arvense*) were found killed in the sunflower field, but these weeds were less susceptible than sunflowers. Sclerotia were present within the stems, and isolations yielded the same fungus as was obtained from sunflowers. Mr. I. L. Conners also found the disease some distance away along the bank of the Red River on wild sunflower, *Helianthus tuberosus* and on Sow Thistle (*Sonchus arvense*). Infection of the soil in the field planted to sunflowers probably came about either from having been present on some vegetable once grown in a garden patch in one part of the field or from a natural infection of the soil by the fungus having grown on some wild host such as the wild sunflower. It may be noted that in most cases where the disease has been found in Manitoba, the sunflowers were grown beside or planted after vegetables. The same areas affected in

Figure 2.—The development of mycelium and sclerotia of the fungus on parsnips.

1920 showed the disease on the succeeding crop of sunflowers in 1921, and it was encouraging to note that the disease was not conspicuously worse in 1921 than in 1920, despite the opportunities for spread of the fungus in the field, the presence of infected débris in the field, and a damper season in 1921. The losses were, however, considerable in extent, and the disease is sufficiently threatening to the sunflower crop to deserve careful attention.

The Sclerotinia lives over winter in the soil, as is indicated by the fact that the same areas were affected in 1920 and 1921. Affected sunflower plants rarely produce seed, and no evidence was obtained that

Figure 3.—Leisons caused by the parasite, and externally produced sclerotia on sunflowers found affected in the field, August 19th, 1921.

the seed carries the organism. Tissue cultures were made in 1920 from the stem 48, 36, 24, 8, 6 and 3 inches above affected areas on stems and from opposite the tip of a lesion which extended further up one side of the stem than the other. In none of these cases was Sclerotinia mycelium obtained. The organism may, however, be obtained readily from tissue cultures from affected areas. It is evidently not systemic in affected plants.

Inoculations were made during the winter of 1920-'21 upon sunflower and other plants in the greenhouse, and upon various vegetables. Cultivated sunflower plants about one foot high were killed by inoculation of the base of the plants with mycelium from a pure culture of the fungus and Sclerotia developed within the stem. The lack of light allowed only a slight growth of the plants. In the laboratory inoculations, a culture of the fungus into carrots and parsnips readily produced rot, and a considerable rot was produced upon potato tubers. Onions rotted only slightly. Turnips and beets did not rot in the preliminary tests made. Corn plants were not affected when the fungus was inoculated into the base of the plants in the greenhouse.

Tests were made during the summer of 1921 relative to the rate and manner of spread of the disease in the field. An isolated plot of sunflowers was planted, and on July 26th, 1921, inoculations were made by placing mycelium from an affected plant against needle punctures at the base of two plants; then the diseased stalk was placed between two uninjured plants and merely pressed into the surface of the soil. In one week's time, both punctured plants showed the disease conspicuously, and the plants on either side of the diseased stem, also were blackened at the base by the attack of the fungus. The spread continued to adjacent plants; on Aug. 18th, 5 plants along the row in one case and 11 plants in the other case in which punctures were made, were diseased. The fungus had spread along the row and caused rot for a distance of 2½ feet in 22 days in the case in which 11 plants were affected. No plants in the plot, other than these mentioned, became affected. No injuries except those that may naturally occur are necessary for infection.

Tests were not made with varieties of sunflower to determine whether resistance to the disease is to be found. The fact that so many hosts, including wild sunflowers and other weeds, may be attacked makes the prospect for resistance, especially where the soil is heavily infested with the fungus, not very bright. Healthy plants are sometimes found in areas in the field in which practically every plant is

diseased; but these have no doubt merely escaped the disease; no definite evidence of resistance of individual plants was found.

Grains or grasses are not known to be attacked by this Sclerotinia. A crop rotation in which sunflowers follow grain crops would seem to offer hope of lessening the danger of the development of this disease, although tests will have to be made as to the length of time the fungus may remain active in the soil under various conditions. It is evident that the sunflower field should not be on or too close to the plot of ground used for garden on account of the danger of infection from the fungus being present on vegetables.

Summary.

A stem-rot of the cultivated sunflower, caused by a species of Sclerotinia, appeared during 1920 and 1921 in Manitoba. The disease is characterized by a rotting of the stem, usually at the surface of the ground, and by wilting of the plants. Certain weeds may also be affected as well as carrots, parsnips, and other plants. The fungus lives over winter in the soil. It attacks sunflowers when they have attained considerable growth. The fungus spreads rapidly in the field. It was not found to be systemic in affected plants. Sunflowers should not be replanted on fields which harbor the organism.

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EDITORIAL NOTE.

Dr. G. R. Bisby, the author of the foregoing article, has accepted a year's leave of absence in order to accept a position with the Imperial Bureau of Plant Pathology recently established at the Kew Gardens, London. There are over 50 appointments of plant pathologists in the overseas Dominions, Colonies and Protectorates of the British Empire, and this Central Bureau of Plant Pathology, in London, will serve as a central clearing house and co-ordinating agency for these scattered specialists.

CONSPICUOUS VALUE OF PURE BRED STOCK.

The value of purebred live stock, say specialists in the United States Department of Agriculture, is most noticeable in those cases in which the capability of the animals is measured most directly. Among farm animals the best illustration can be found in dairy cattle, though careful yearly tests of milk and butterfat production are relatively recent affairs. The enormous differences among dairy cows when given the same opportunity have been brought out clearly in a great number of cases, and these differences are strongly inherited through both the sire and the dam. The average production for purebreds and grades is much above the average of all milk cows, which is about 4,000 pounds of milk and 160 pounds of butterfat annually.—*Weekly News Letter, U. S. Department of Agriculture.*

Greenhouse Cucumber Breeding

By W. J. STRONG
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(Paper read at Convention of Northern Great Plains Horticultural Association, recently held at Ottawa).

Compared with other horticultural crops the greenhouse cucumber occupies a rather minor position. It is not a cheap crop to produce, neither is it one that enjoys an unlimited market, and it can hardly be considered a staple crop such as cabbage, carrots, beans or onions. It ranks more as a luxury and is quite an aristocrat compared with its humble outdoor brothers.

As an article of food the cucumber, whether grown outdoors or under glass, is not looked upon with much favour by dietitians. Its actual value in calories is certainly not very great and most people consider that it is very indigestible. While cucumbers may not be of great food value yet they are appreciated by thousands of people as a relish.

The long green English type is not much in favour on our markets except in a few cases and on private estates. The market wants a cucumber that runs about eight inches long and two inches in diameter, so that 1½ dozen will pack into an eleven quart basket; but it is not altogether a matter of packing. Dealers and retailers find that the average families do not care to buy two feet of cucumber at a time. They much prefer to buy smaller fruits and buy them oftener.

So much for the size of cucumber required, which is comparatively easy to get.

What is our ideal cucumber?

Briefly, it should be about 8 inches long, 2 inches in diameter, straight, of even size from end to end, with no neck and without a heavy shoulder or small tip. It should be dark green, smooth, with white spines or spineless, and last but not least should set fruit freely without pollenation.

This free setting without pollenation is very important as it makes it unnecessary to resort to artificial pollenation either by hand or by bees. Artificial pollenation is laberious and expensive and bees do not work to advantage in the humid atmosphere of the cucumber house.

No pollenation of course means no seeds, and fruits without seeds keep in better condition on the vines than where seeds are formed. But seedlessness may have its disadvantages. We all appreciate seedless oranges and seedless raisins and most of us no doubt prefer seedless cucumbers, but the writer knows of one instance where a customer returned some seedless cucumbers with the complaint that they were not ripe.

Now it may seem that undue emphasis is being placed on the mere selling qualities of this crop, but that is really what we must keep in mind. We must produce something that the consumer wants or can be taught to want. The ordinary grower is not much interested in the principles of plant breeding. It is up to practical plant breeders to understand and be able to apply these principles and produce new fruits, vegetables and flowers, that will be of greater value or beauty than anything we have at present.

The need of the smooth, small, seedless cucumber must have been felt for a number of years as the original cross which has given us our new variety was made in 1910 by Mr. A. H. Maclennan, at that time lecturer at the Ontario Agricultural College and now Vegetable Specialist for Ontario.

In making this cross three varieties were used: first, Suttons Everyday was crossed with Fisks White Spine, then this hybrid was crossed with Princess.

A brief description of each of these varieties will not be out of place.

Suttons Everyday is of the long green English type with a bottle neck. It sets fruit freely without pollenation and is consequently seedless. It has a smooth skin

MANAGRA

THE WHEAT RUST PROBLEM

By G. R. Bisby

References in the Bible and other ancient publications indicate that wheat rust has troubled man ever since he grew wheat for food. For thousands of years the blighting of crops by rust was attributed to evil spirits or to the dispensations of Providence. In modern times the disease has been charged to abnormal development of the plant or merely to weather, ideas which are still held by the majority of people in spite of the fact that it has been known for more than a century that rust is caused by a fungus. About sixty years ago it was shown that red rust and black rust are not distinct, but different stages in the life cycle of the same organism, and that the stem rust of grains spends part of its life on the barberry.

The farmer in Western Canada is so seriously confronted with the loss from rust of wheat and other grains that he naturally frequently asks why something cannot be done to prevent its ravages. He is familiar with the simple and effective formaldehyde treatment of seed for smut; he wants some treatment for the prevention of rust. No seed treatment, however, can be effective in preventing rust, for the disease is not transmitted by the seed. No plant disease has received such searching inquiry as has rust during the past fifty years; yet, in spite of the best efforts scientists have been able to give to the problem, no preventive measure has been found which will eliminate the disease. A great mass of facts has, however, been accumulated, and there are now reasons for hope that the baffling rust problem may comparatively soon be solved.

The facts in regard to the black stem-rust of wheat and other cereals are these: About the first of June any barberry bush present in Manitoba will begin to show rust on the leaves in the form of "cluster cups," tiny cup-like structures closely clustered together on the lower surface of the barberry leaves. Each cluster cup contains thousands of spores, or minute "seeds" of the rust. These spores are blown from the barberry to wheat, barley, wild barley or squirrel tail grass, wild wheat grass, wild rye, or to other grasses; and red rust then forms on these hosts about the last part of June or the first of July. The red rust spreads from plant to plant in the wheat fields, and on the other plants mentioned. If the weather is warm and damp, the spread of red rust may be very rapid, because the rust requires moisture and warmth to germinate and cause infection. The red rust uses up the food and moisture of the wheat plant, and breaks through the epidermis of the stem or leaf to set free the red spores which can be seen rising like a cloud whenever a badly rusted plant is shaken. As the wheat or grass plant nears maturity, black rust is produced instead of red rust. The popular conception that it is the black rust that causes the greatest damage is not exactly correct; the occurrence of black rust indicates a weakening of the plant from the attack or rust, or the beginning of weather unfavorable to continued production of the red stage. The black spores do not spread to other wheat plants; they are incapable of germinating until the following spring, and then can cause infection only on the barberry, and so begin the story over again.

The stem rust attacks wheat, oats, barley, rye, timothy, and many wild grasses. There is, however, a high degree of specialization exhibited by the

rust; while the rust will pass from wheat to barley, it does not go from wheat fields to oats or rye. Similarly, the rust on oats does not go to wheat or rye. This specialization also holds for wild grasses; quack grass, for example, is rusted only by the form of rust that grows on rye. The rust attacks the same cereals and grasses after having grown on the barberry as it did previously. Workers have recently found that the specialization of rust exists also between varieties of wheat; the rust that attacks Marquis wheat may not attack Durum wheat, and vice versa.

Farmers are able to lessen somewhat the damage from rust by cultural practices which make for earlier maturity or less rank growth of grain. The eradication of the barberry deserves special consideration as a preventive measure. It has long been noticed by grain growers that rust is worst in the vicinity of barberries; although, until 1865, no one knew just why. Thus, there was passed in 1726 a law in Connecticut providing for the destruction of barberries, "it being by plentiful experience found that where they are in large quantities they do occasion, or at least increase, the blast on all sorts of English grain." The barberry, nevertheless, was planted far and wide. Several years ago Denmark systematically destroyed the barberry bushes present, and has suffered much less from rust since that time. During the past few years efforts have been made to destroy the barberry bushes in Manitoba and in the north central United States. There are still barberries in Manitoba and the states to the south, however; but efforts to remove them are being continued. While no one can promise that complete eradication of the barberry would eliminate rust in this region; yet it is certain that rust is worse in the vicinity of barberries, and every bush should be removed or reported to the weed inspectors.

Aside from the barberry, there is one other possible means by which the rust can get through the winter in Manitoba, and that is by a few red spores living through on wheat, wild barley, or other grass. The rust does overwinter in the red stage in the southern half of the United States; but much search has failed to find one red spore which has lived long enough in Manitoba or the states immediately south to cause infection on grasses or wheat in the spring.

Perhaps a considerable amount of the rust that appears here each summer is blown in by winds from the south. The complete eradication of the barberry in North Dakota and Minnesota will, therefore, help Manitoba.

One of the best hopes for the future is the production of varieties of wheat resistant to rust. Khapli, an Indian emmer, is resistant to all forms of wheat rust so far found. It can be crossed with Marquis, for example, with the possibility of developing a hybrid combining the good qualities of Marquis with the rust resistance of Khapli. Many trials have heretofore been made to develop varieties of wheat resistant to rust; most of these attempts have failed because the workers did not then know that there are so many forms of the rust with which the hybrids would have to contend.

Wheat rust, presenting one of the most complex and baffling problems with which plant pathologists have had to deal, will sooner or later be controlled.

Bless the man who first invented sleep,
But blast the man, with curses loud and deep,
Who first invented and then went round advising
That artificial cut-off, early rising.

Potato Growing in Northern Manitoba

By G. R. BISBY AND F. W. BRODRICK
Manitoba Agricultural College, Winnipeg

Garden plot of potatoes in the Swan River Valley, Manitoba. Mr. Cotton's farm. July, 1921.

MANITOBA produced an average of nearly six million bushels of potatoes per year during 1918, 1919 and 1920. This Province will doubtless produce many more potatoes in the near future. The climate is in many ways well suited to potato growing, and the value of a cultivated crop in conjunction with grain growing is receiving recognition.

Potato production in Manitoba has in the past been held back by several factors: the lack of established marketing relations; the occurrence of diseases, especially leaf roll and mosaic and the growing of numerous so-called varieties. These difficulties are now being overcome, especially through the efforts of the Manitoba Department of Agricultural Extension, the Department of Horticulture of the Agricultural College at Winnipeg and the Manitoba Potato Grower's Association.

The Potato Grower's Association, realizing that steps must be taken to standardize the varieties of potatoes grown, selected as standard the following types: Early Ohio, Beauty of Hebron, Irish Cobbler and Green Mountain. In order to improve the quality and lessen the amount of disease in the stock grown, a carload of Canadian Certified Cobblers was brought in from Western Ontario in the fall of 1919: these gave such good results in 1920 that the Agricultural Extension Service Department arranged in the fall of 1920 for the purchase of some eight or nine carloads of Minnesota Certified Cobblers grown in northern Minnesota. These were widely distributed throughout the Province and should greatly improve the general quality of the potatoes grown; since they are showing up

The field shown was originally covered with trees and bushes such as are seen around the field. Photographs from Dauphin are from fields of Moore and Stevenson.

This view shows a potato planter, with hopper removed, being used to cultivate and hill up the potatoes.

well this year and their progeny will be largely replanted here.

These are points which deserve special consideration, however, and it is the purpose of this article to deal more particularly with potato growing in the north-west portion of the agricultural area of Manitoba.

Manitoba extends from the 49th parallel northwards to the 60th parallel, some 770 miles north of the North Dakota and Minnesota boundary. Farming is carried on, however, only up to about the 53rd parallel, and to this latitude only in the western part of the Province. Lake Winnipeg (which is larger than Lake Ontario) extends for some 300 miles north

(*Continued on page* 18)

POTATO GROWING IN NORTHERN MANITOBA

(*Continued from page* 14)

through the south-central part of Manitoba, and west of Lake Winnipeg are the large Lakes Manitoba and Winnipegosis and many smaller bodies of water. Along, or near, the Manitoba-Saskatchewan boundary are ranges of hills called the Riding, Duck and Porcupine Mountains. The agricultural area extending farthest north in Manitoba is in the valleys west of the lakes mentioned and between the ranges of mountains, or hills.

The Swan River Valley is the most northerly agricultural area in Manitoba. This valley is protected by the mountains on all but the north-east side, and lakes exert an influence on

Treatment of seed potatoes with corrosive sublimate solution, and cutting operations in getting Certified seed ready for planting. Dauphin, Manitoba.

that side. It is 200 to 250 miles north of the International Boundary. The season is, of course, short; but the extremely long days in the summer allow a wonderfully rapid growth of vegetation. Frosts may be expected every month in the year; but there are usually none from the early part of June until the latter part of August. Rainfall is ample here. It has been the writers' privilege to travel over the Swan River Valley where potatoes were seen growing in almost every farmer's garden: occasionally an acre or more is planted. The accompanying illustration shows the appearance of potatoes there on the 9th of July, 1921. This region will probably not soon grow potatoes extensively, however, because of some danger of crop reduction from frost and of the distance from market.

About a hundred miles south and east of Swan River, there is a valley between the Duck and Riding Mountains, centering in the town of Dauphin. Here, the danger of frost is not great and climatic conditions are such that high yields of potatoes can be expected; also, the seed produced should be valuable for more southern use. Potato growing is not as yet much developed in this valley. Moore and Stevenson of Dauphin are the largest growers: they have 90 acres of potatoes in this year. Steps in the production of their crop are illustrated herewith: it will be noted that all the common preventive measures against disease are used in the production of the crop. These growers obtained Certified Cobblers from western Ontario and Certified Early Ohios from Minnesota. Their fields were visited on July 27th, 1921 at which time they were digging a few potatoes for early market. They were obtaining about 125 bushels per acre some two months after planting and, of course, much larger yields will be obtained where the tubers are allowed to mature.

Leaf diseases are not ordinarily of any consequence in Manitoba: late blight is unknown. Blackleg occurs in cool and damp seasons. Wilt is quite common; but does not usually cause much loss. Rhizoctonia is, however, very common and often serious. Leaf roll and mosaic are being eliminated by the use of certified seed. Everything considered, Manitoba is favorably located for potato production: certain areas in the northern part of the agricultural region of the Province offer promise of developing the industry to a considerable extent; and since these areas are near the northern limit of potato production in North America, should provide the very best of northern-grown seed stock for use in the United States.

The Cooperative Potato Spraying Project: Report for 1921

C. R. BISBY, E. E. CLAYTON, W. H. MARTIN, J. T. ROSA, JR., E. A. STOKDYK

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THE COOPERATIVE POTATO SPRAYING PROJECT: REPORT FOR 1921

G. R. Bisby, E. E. Clayton, W. H. Martin, J. T. Rosa, Jr., E. A. Stokdyk[1]

With Notes by Other Workers

This brief report, to supplement the data given in *Phytopath.* **11**, pp. 178-193 is made to bring the results of potato spraying and dusting experiments down to date. It is hoped that these experiments may be continued in the various regions where work is still needed.

Manitoba.—Preliminary tests were made by G. R. Bisby. Late blight has never been recorded in Manitoba, and early blight and tipburn (hopperburn) are not ordinarily serious. Spray and dust were applied in 1921 to a field of Bovee (Beauty of Hebron) potatoes at Winnipeg. The soil was not very good, and somewhat poorer toward one side; however, since the plots consisted of 4 rows sprayed or dusted alternated with 4 check rows, this source of error is compensated. A 5–5–50 Bordeaux was used, applied with a traction sprayer. Since the sprayer had but one nozzle per row, each plot was sprayed twice over at each application, the machine travelling in opposite directions. Three applications of spray were made July 16, 25, and August 4. Sander's copper lime dust was applied with a hand duster to the dust plots July 18, 27, and August 8. The sprayed plots were noticeably different during the summer, and remained green about 2 weeks longer than the check plots. No difference could be noted between dust and check plots. The potato beetle had been controlled on all plots with poison before spraying and dusting began. Some early blight and tipburn occurred, being worse on plots not sprayed. Yields were taken from the 2 middle rows of each plot.

TABLE 1

Yields in Manitoba in 1921

Treatment	Rows No.	Ave. yield per acre bu.
Sprayed	2, 3	178.2
Check	6, 7	127.9
Sprayed	10, 11	170.5
Check	14, 15	152.1
Sprayed	18, 19	173.2
Check	22, 23	142.1
Dusted	26, 27	149.8
Check	30, 31	123.6
Dusted	34, 35	113.7
Check	38, 39	97.2
Dusted	42, 43	92.9
Check	46, 47	89.1

[1] Coöperative project of the Advisory Board of American Plant Pathologists.

We may summarize table 1 as follows:

Average yield of 3 sprayed plots	174.0 bu. per acre
Average yield of 3 adjacent checks	140.7 " " "
Average increase from spraying	33.3 " " "
Average yield of 3 dusted plots	118.8 " " "
Average yield of 4 adjacent checks	113.0 " " "
Average increase from dusting	5.8 " " "

These results indicate that spraying pays in Manitoba.

Ohio.—E. E. Clayton carried out an extensive series of coöperative experiments on potato spraying and dusting in Ohio during 1921. Forty-four spraying tests were made, principally on areas of 1 acre or one-half acre in fields in Cuyahoga and Lake Counties.

The Rural New Yorker variety was grown in most cases, although several other varieties were tested. Most of these plots were sprayed 3, and 5 or 6 times, and 5-5-50 Bordeaux mixture was used. Various methods of application were tried. Most of the potato fields were planted June 15 to 20, and the spray was applied at about two week intervals, beginning usually early in July. Of these 44 spray tests, increases in yield were obtained in 41 cases and in only 3 cases were slight decreases found on sprayed areas. The data obtained from the 44 plots may be summarized as follows: An average of 32.5 bu. per acre increase was obtained from all sprayed plots. This is an average of 29.5 per cent increase over the unsprayed plots. The average cost was $10.27 per acre for spraying, and the average net profit from spraying during 1921 is figured at $42.65 per acre. The more important results are summarized as follows:

No. of nozzles[1]	Pressure	Increase in yield per acre
2 (5 tests)	75 lbs. (traction)	16 bu.
3 (16 tests)	75 lbs. (traction)	27 "
3 (23 tests)	200 lbs. (power)	39 "

Relation of number of applications of spray to yield and net profit in Ohio

No. sprays	Increase in yield per A.	Net profit per A. from spraying[2]
Traction sprayer		
3 (11 tests)	18.7 bu.	$22.42
5 or 6 (10 tests)	36.4 "	$36.80
Power sprayer		
3 (8 tests)	30.7 bu.	$42.21
5 (11 tests)	44.4 "	$61.30

The results from these spraying tests indicate a greater or lesser degree of control of hopperburn (tipburn), which was the major leaf disease in Ohio in 1921. Late blight was absent.

The most efficient spraying with Bordeaux 5-5-50, using 3 nozzles to the row, 200 lb. pressure and 5 applications, gave perfect control of tipburn from the point of view of the practical grower, and marked increase in yield.

Mr. Clayton also tested the complete potato dust as prepared by the Niagra Sprayer Co., and applied with a Niagra power potato duster. The results obtained on fields near Madison, Lake County, Ohio, are given in table 2.

[1] A number of men who sprayed with one nozzle to the row and 75 lbs. pressure reported no increase in yield.

[2] Computed from figures supplied by the growers.

TABLE 2

Results of dusting potatoes in Ohio in 1921.

Coöperator*	Variety	Date planted	Dates dusted	Area dusted	Yield per acre Dusted	Yield per acre Check	Increase	
				Acres	Bu.	Bu.	Bu.	Per cent
Mr. Benjamin	Wellington	June 1	July 7, 21 Aug. 5, 19 Sep. 3, 7	½	111.6	106.2	+5.4	+5.1
Mr. Kelen	Wellington	June 10	July 21 Aug. 5 Sep. 3	½	49.2	40.4	+8.8	+21.8
Mr. Faust	Holloway	June 1	July 7, 21 Aug. 19	½	70.0	72.6	—2.6	—3.6
Mr. van Gulick	Unknown	June 1	July 7, 21 Aug. 5, 19 Sep. 3, 7	½	85.8	71.4	+14.4	+20.2

* Three other coöperators reported no increase in yield from dusting but accurate yield data were not obtained.

New Jersey.—W. H. Martin obtained the following results in 1921:

1. Salem Co. A level field of Irish Cobblers on sassafras to sandy loam soil, fertilized with 2,000 lbs. 4-8-7 fertilizer per acre, was sprayed with home-made 5-5-50 Bordeaux mixture, except the check plots, which received only arsenate of lead. The Bordeaux was applied with a traction sprayer, three nozzles per row, 175 lbs. pressure, and 100 gallons per acre were applied. The first application of Bordeaux was made when the plants were seven inches high. No late blight, and only a trace of early blight, was present. Tip-burn was abundant. The sprayed plots remained green longer than the checks, the plots receiving 4 applications remaining green longer than those sprayed 3 times. Plots dug August 26, 1921; yield as follows:

Treatment	Yield per acre, bu.	Average
Check, (plots 1, 4, 7, 10)	150.8, 155.7, 157.4, 129.5 resp.	148.3
Bordeaux, June 13, 20, July 1, 8, (plots 2, 5, 8)	227.8, 239.3, 221.3 resp.	229.5
Bordeaux, June 13, 20, July 1, (plots 3, 6, 9)	214.2, 213.5, 178.1 resp.	201.9

2. Cumberland Co. Irish Cobblers were planted on sassafras loam, and fertilized with 1800 lbs. 4-8-7 fertilizer per acre. The last four plots were on an area somewhat lower than the remainder of the field. Bordeaux was used as above, except that the dates were different. Early season sprayings were May 26, June 1 and 13. Late season applications June 20 and 29; all season spraying included all five dates mentioned. On June 29 flea beetles were numerous on the check plots (arsenate of lead only applied) and on plots receiving early applications of Bordeaux; very few on plots which had the late applications. No early blight by June 29, but some leaves yellow from dry weather. Plots dug August 10; yield:

Treatment	Yield per acre, bu.	Average
Check, (plots 1, 4, 7, 11, 14)	90.2 109.6 128.0 131.6 134.5 resp.	118.8
All season, (plots 2, 6, 10)	116.8, 127.9, 144.3 resp.	129.7
Early, (plots 3, 8, 12)	120.8, 125.1, 152.8 resp.	132.9
Late, (plots 5, 9, 13)	120.3, 136.1, 135.8 resp.	130.7

On the above field a test of 20–80 copper lime dust was made. The dust was applied May 26, June 13, 20, and 29 by means of a power duster. The dust did not afford much protection from flea-beetles and on June 29 little difference between check and dust plots could be noticed. The dusted area yielded at the rate of 120.7 bu. per acre, in contrast to 118.8 bu. on the check plot.

3. Salem Co. Irish Cobblers planted July 25 as a second crop for seed purposes on a level field of sassafras loam. The spray plots were sprayed with home-made 5-5-50 Bordeaux with a traction four-row sprayer with three nozzles per row. Dust plots received, in one series, 20–80, and in another 15–85 copper lime dust applied with a hand duster, and the plants were thoroughly covered. Check plots were not sprayed at all, since insects were not present. Dust and spray applied September 1, 10, 20, 27, October 5, 14. Plots dug October 29.

Results as follows:

Treatment	Per cent of leaves dead			Yield per acre
	Oct. 5	Oct. 14	Oct. 21	bu.
Check	61.2	91.1	98.0	125.0
Bordeaux	1.3	15.3	55.0	163.5
20-80 dust	14.0	43.3	88.0	144.1
15-85 dust	12.8	46.6	92.0	139.4

The check plots suffered considerably from early blight and tipburn. The dusted plots were affected to a lesser extent by these diseases, and the Bordeaux plots but little.

4. Salem Co. Late crop Cobblers. The following tests were made by growers who formed a "spray ring." A traction sprayer which developed 175–200 lbs. pressure was used, and 5-5-50 Bordeaux was applied at the rate of 100 gallons per acre, at a cost of $2.06 per acre per application. Early blight and tipburn were the only diseases present. The yields in bu. per acre were as follows:

Test I. Sprayed 4 times, 160.1 bu.; check, 119.1 bu.

Test II. Sprayed 4 times, 213.5 bu.; sprayed 2 times, 198.6 bu. Check, 161.0 bu.

Test III. Sprayed 3 times, 213.4 bu.; check, 162.7 bu.

These results supplement previous data (see also N. J. Rept. **1920**: 577–587, 1921 and N. J. Circ. 122) and indicate that spraying Cobblers in New Jersey will result in increased yield even in the absence of late blight. Fair results were obtained from copper-lime dust on the late crop, in spite of the dry weather, but during 1921 dusting did not give as good results as Bordeaux.

Missouri.—J. T. Rosa, Jr., reports tests upon Early Ohio potatoes from northern Michigan which were planted at Columbia, Mo., March 17, 1921, and given 4 applications of 4–4–50 Bordeaux during May and June, both with and without lead arsenate and nicotine sulfate. The sprayed plants remained green about 3 weeks longer, and when dug August 28 yielded 34.2 per cent more than the checks. However, the tubers from the sprayed plots bore so many knobby second growths that the actual quantity of marketable potatoes was less than that obtained in the check plots, which bore few secondary growths. The Early Ohio variety has been found previously to be more subject to second growths than other early varieties grown at Columbia. Perhaps other varieties, such as Irish Cobblers, would not react in this manner. The weather conditions during 1921 were probably conducive to secondary growth of the tubers, since short wet periods alternated with longer dry, hot ones. These conditions were particularly apparent the latter part of the season when only the sprayed plants were alive. Knobby tubers should not necessarily be less valuable than uniform tubers for seed purposes. Tests of soil moisture and temperature relations, and of the state of dormancy in tubers whose growth is checked by weather conditions, need to be made.

Leaf hoppers became abundant during the latter half of the growing season on the above plots. Very little early blight and no late blight occurred. Tipburn was serious.

Pyrox did not keep the plants green quite as long as Bordeaux, but the yield was increased just as much over unsprayed plots as was the case with Bordeaux.

Kansas.—E. A. Stokdyk, working in coöperation with L. E. Melchers, submits the following data obtained in coöperative potato spraying tests with M. R. Kelsey, Topeka, Kansas, in 1921. The plots were one acre in size. Home made Bordeaux mixture with poison was used. A power sprayer, equipped with two nozzles to the row and spraying ten rows at a time at a pressure of 150 to 175 lbs., was used. Approxi-

mately 100 gallons were applied per acre. Check plots were sprayed with poison only. Plots sprayed 4 times had applications on May 23, June 3, 9, and 21. Plots sprayed 3 times had the May 23 spray omitted. Fields planted about March 30, and dug July 15 to August 15. Leaf hoppers present in the latter part of the season. Tipburn and early blight about an average for Kansas, and as bad as or worse than in previous spraying tests. Late Blight does not occur in Kansas. The vines sprayed with Bordeaux remained green longer than the unsprayed ones.

TABLE 3

Results of spraying Early Ohios in Kansas in 1921

Spray applied	No. applications	Yields per acre, bu.	Cal. increase[1] per acre, bu.
Check	–	122.58	
Bor. 3–4–50	4	158.83	27.6
Check	–	139.88	
Bor. 3–4–50	3	191.80	43.7
Check	–	156.58	
Bor. 4–5–50	4	179.58	22.2
Check	–	158.25	
Bor. 4–5–50	3	160.00[2]	5.9
Check	–	150.00[2]	
Bor. 4–8–50	4	155.90[2]	6.5 loss
Check	–	174.81[2]	
Bor. 4–8–50	3	158.50[2]	0.65
Check	–	140.90[3]	

TABLE 4

Results of spraying Irish Cobblers in Kansas in 1921

Spray applied	No. applications	Yields per acre, bu.	Cal. increase per acre, bu.
Bor. 3–4–50	4	310.4	20.7
Check	–	289.7	
Bor. 3–4–50	3	310.9	24.6
Check	–	282.9	
Bor. 4–5–50	4	340.9	50.9
Check	–	299.0	
Bor. 4–5–50	3	279.1	5.4 loss
Check	–	270.0	
Bor. 4–8–50	4	285.5	34.2
Check	–	232.7	
Bor. 4–8–50	3	231.8	6.5
Check	–	218.0	

[1] Increase obtained by averaging the yield of two adjacent check rows, and subtracting the result from the yield of the sprayed row.

[2] Heavy rains had produced some irregular areas in these plots.

These results show an increase of 15.7 bu. per acre, or 10.5 per cent, from spraying Early Ohios, and an average of 21.8 bu. per acre, or 8.2 per cent, increase from spraying Irish Cobblers. Although these are not large increases, they indicate better results from Bordeaux under 1921 conditions than were obtained in the three previous seasons. The results up to date seem to indicate that with the methods used Bordeaux sprays for the potato crop in Kansas are of questionable value.

Eastern Canada.—P. A. Murphy gives (Canada Dept. Agr. Div. Bot. Bull. 44, 1921) valuable data on spraying in eastern Canada. The best results in fields were obtained from high pressure and three nozzles per row, although on small plots even better blight control can be obtained with hand sprayers. Bordeaux mixture was found to be better than Burgundy. Spraying before rains gave better results than spraying after rains. Many other data are given. The use of fungicides on potatoes in eastern Canada is rendered imperative by the prevalence of Phytophthora. An average of 130.5 bu. per acre yearly increase in yield of marketable potatoes was obtained from spraying with Bordeaux. Imperfect spraying, by keeping the vines green but not preventing development of Phytophthora, may result in more tuber rot than occurs on tubers from unsprayed fields.

G. E. Sanders finds that white arsenic may be combined with Bordeaux mixture and applied without injury to plants. (Agr. Gaz. Canada **7,** No. 1, 1920; Proc. Ent. Soc. Nova Scotia **6;** 8. 1921). He gives reports on dusting, but not specifically as applied to potatoes (Sci. Agr., Canada, Vol. **2,** 1921; Ann. Rep. Fruit Growers' Assn. Nova Scotia, **1921:** 66–92.)

Pennsylvania.—E. L. Nixon obtained in coöperative tests in 1921 even better results from the use of Bordeaux than those previously reported for Pennsylvania. Ten thousand one hundred and forty acres in 57 counties were included in spraying tests. An average increase of 74.3 bu. or 46.7 per cent was secured in the 402 demonstrations. Outfits yielding a minimum pressure of 200 lbs. were used in all cases. These results were obtained in a year with less late blight than occurred during 1918, 1919, or 1920. The spraying served to keep the plants alive over the extended drought which was fatal in many fields to the unsprayed plants.

West Virginia.—N. J. Giddings reports the following for 1921: At Wheeling, Irish Cobbler sprayed May 27, June 6, 20, and 30 with 5–5–50 Bordeaux mixture gave a 25 per cent increase in yield over the checks using hand sprayers. The plants were practically free from all leaf diseases except tipburn.

At Parkesburg, late potatoes (Carman) sprayed with hand outfit June 12, 16, and 27 gave a 20 per cent increase. Early potatoes sprayed May 21, June 2, 16, and 27 gave no increases. Tip burn was serious in both cases.

At Fairmount, early potatoes sprayed with hand outfits May 14, 26 and June 4, 17 and July 1 gave a 33.3 per cent increase.

At Davis three applications of spray using a power sprayer equipped with 3 nozzles to the row gave an average increase of 33.5 per cent in yield. A very little late blight was present at Davis.

Kentucky.—W. D. Valleau, Mr. Gardner and A. J. Olney report increases in yield and reduction in leaf hopper injury from the application of Bordeaux in 1921.

Indiana.—H. S. Jackson reports no authentic record of late blight in Indiana. Early blight is worst in the southern half of the state. Tipburn is very serious. Many commercial growers spray 3 to 5 times with 4–4–50 Bordeaux, which seems to be warranted by the partial control of tipburn secured.

British Columbia.—J. W. Eastham reports that spraying is not common over most of British Columbia because the Colorado beetle is absent, and late blight is absent over much of the province. Early blight may be destructive. An experiment at Sardis in 1918 indicated good results from Bordeaux against late blight.

Arizona.—J. G. Brown reports that Bordeaux checked the early blight attack in 1921 in Arizona. This disease spreads rapidly in Arizona during rainy periods unless the plants are sprayed.

H. W. Barre (*South Carolina*), J. G. Leach (*Minnesota*), J. A. Elliott (*Arkansas*) and M. B. McKay (*Oregon*) report no further data, nor have results for 1921 been received or noted from other regions not mentioned in this summary. Data from *North Dakota* by W. G. Colley and Dr. Weniger uncertain because of unfavorable weather.

SUMMARY

From the results obtained in 1921, it would seem that Ohio and Manitoba may be added as regions where the use of Bordeaux for potatoes is profitable. Supplementary data from New Jersey, West Virginia, Pennsylvania, certain other areas, and published results for Canada indicate further the value of spraying. Some further suggestions as to procedure, etc., may be gathered from the 1921 results. In the states of Kansas and Missouri, the value of Bordeaux is questionable.

During 1921 dusting trials on potatoes in New Jersey, Ohio and Manitoba gave results inferior to those obtained in spraying tests. This inferiority of dust in 1921 may perhaps be explained in part by the dry season and the absence of late blight in the areas where dust was tested.

PRELIMINARY LIST OF MANITOBA FUNGI

BY

G. R. BISBY AND A. H. R. BULLER

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PRELIMINARY LIST OF MANITOBA FUNGI.

By G. R. Bisby and A. H. R. Buller.

Manitoba extends north of Minnesota and North Dakota from the 49th to the 60th parallels of latitude. Manitoba is, therefore, in the same latitude as the British Isles, and extends, roughly, from the parallel of Paris and Vienna to that of Christiana and Petrograd. Climatic conditions are quite different, however, from those of most of the corresponding area in Europe.

Many species of Phanerogams attain their northern limits in Manitoba, and various plants reach their eastern or their western limits in this province, which marks a transition from a wooded rocky region in the eastern part to drier plains in the western portion. Manitoba is a region of considerable mycological interest.

This list is very incomplete: in only a few groups, such as the rusts and polypores, has anything more than a general preliminary survey been made, and in no case can this list purport to approach completeness. It does, however, serve to extend the range for a considerable number of species of fungi, and records the occurrence of such fungous diseases as have been observed, especially during 1920 and 1921, in the province. The collections have practically all been made in the southern quarter of the province, and principally below the 51st parallel. One trip was made to the Swan River Valley, just above 52° north latitude. The fungi of eastern Manitoba are represented largely by collections from Kenora and Minaki, which are in Ontario, but near the Manitoba line, and which are representative of conditions in south-eastern Manitoba. The highly interesting far north of Manitoba is as yet little surveyed for fungi.

This list to a considerable extent is dependent upon, and its accuracy is greatly heightened by, determinations made by various specialists. Grateful acknowledgment is made to those who have determined or corroborated the determinations of various specimens, and also to Professor V. W. Jackson, Mr I. L. Conners (marked "I.L.C."), and others who have aided in making collections, and in determining hosts. The initial of those who have made determinations of fungi is given in each case: if no initial follows, the identification is by the writers. The key to these initials is as follows:

Br. = Dr J. F. Brenckle, Kulm, N.D. Pyrenomycetes, etc.
B. = Dr E. A. Burt, Missouri Botanic Gardens, St Louis, Mo. Thelephoraceae, etc.

D. = Dr J. J. Davis, Univ. of Wisconsin, Madison, Wis. Parasitic fungi.
E. = Dr W. T. Elliott, Arden Grange, Tanworth-in-Arden, Warwickshire, England. Myxomycetes.
F. = Prof. W. P. Fraser, Univ. of Saskatchewan, Saskatoon, Sask. Rusts, etc.
J. = Prof. H. S. Jackson, Purdue Univ., Lafayette, Ind. Certain Rusts and Smuts.
K. = Dr C. H. Kauffman, Univ. of Mich., Ann. Arbor. Mich. Certain Agaricaceae.
L. = Miss G. Lister, Leytonstone, England. Myxomycetes.
Ll. = Mr C. G. Lloyd, 309, W. Court St., Cincinnati, Ohio. Various Hymenomycetes.
V. = Dr L. O. Overholts, State College, Pa. Polypores, etc.
S. = Dr F. J. Seaver, New York Botanical Gardens, New York City. Certain Ascomycetes.
W. = Miss E. M. Wakefield, Kew Gardens, Surrey, England. Various fungi.

In addition to these, other specialists whose names are given have determined certain species.

Specimens from 500 to 1000 inclusive are at the University of Manitoba; other numbers are at the Manitoba Agricultural College. Where no locality is cited, Winnipeg or its environs is to be understood. Where no collector's name is given, one or the other of the writers made the collection; the number indicates which one. Thus, "Arcyria occidentalis Lister, 673*L*, 343*E*" means that both specimens were collected at Winnipeg, No. 673 by A. H. R. Buller, part of the collection being sent to Miss Lister, who made the determination; the remainder is filed at the University of Manitoba. No. 343 was collected by G. R. Bisby, and part of it sent to Dr Elliott, who furnished the name, the remainder being deposited at the Manitoba Agricultural College. It was not considered necessary to include dates of collection unless they were out of the ordinary. Collections from the Swan River Valley were made on July 1st to 13th, 1921; from Gilbert Plains and Ste. Rose du Lac and vicinity, July 25th to 31st, 1921. Collections from Minaki and Kenora have been made principally in September and October, and by A. H. R. Buller unless otherwise noted.

Where no number is given in connection with a species the specimen is not preserved, but its authenticity is considered reasonably accurate, unless a question-mark is appended.

This list is believed to cover nearly all the species of fungi that have ever been collected in Manitoba. The writers have gone over the list of the Manitoba fungi which are at Ottawa and have checked over the rust and smut portions of the North American Flora as well as certain other publications which might contain references to fungi from Manitoba. Apart from the collections of the writers and Messrs Fraser, Conners, and V. W. Jackson, probably few collections of fungi from this province have been made. Various references to Canadian fungi were checked, but in practically every case no collections had

been made in Manitoba, except in the case of Professor Macoun's list of lichens. References to various Manitoba fungi are, however, given in "Researches on Fungi" and other papers by A. H. R. Buller.

The nomenclature used varies somewhat: Dr Kauffman was followed for names of Agarics, Dr Overholts for Polypores, and Saccardo for many fungi. In general the writers have endeavoured to use the standard names for the fungi included. The names of hosts are taken largely from Britton and Brown's Flora.

Dr Davis has furnished the description of a new Cercospora for this list, and Mr Lloyd has considered a Ptychogaster sent him to be a new form. Two or three species are recorded for the first time for North America. In almost every case, however, the fungi found were those which had already been described for North America. Further and more critical search will of course extend this list, and the writers believe that a survey of Northern Manitoba will reveal a number of interesting fungi.

This list contains 574 fungi, as follows: Myxomycetes 34, Bacteria 8, Phycomycetes 20, Ascomycetes 62, Imperfect fungi 38, Smuts 20, Rusts 80, Polypores 63, Agarics 108, Thelephoraceae 36, other Basidiomycetes 57, Lichens 48.

MYXOMYCETES.

Parasitic species have not been found in Manitoba.

Acrasieae: Dictyostelium mucoroides Bref., observed by A. H. R. B.
Exosporeae: Ceratiomyxa fruticulosa (Muell.) Macbr., 326*E.*, 1111, twice found in abundance on old wood.
Endosporeae: Arcyria denudata (L.) Wettst., 674*L.*
A. incarnata Pers., 658*E.*
A. incarnata var. fulgens Lister, 675*L.*
A. occidentalis Lister, 343*E.*, 645*E.*, 673*L.*
A. stipata Lister, 1241*L.*, 1242*L.*
Badhamia macrocarpa (Ces.) Rost., 659, 660.
B. panicea (Fr.) Rost., 643*E.*
Comatricha irregularis Rex., Carman, A. R. Skinner, 676*L.*
Craterium leucocephalum (Pers.) Dittm., 340*E.*
Diderma globosum Pers., 646*E.*, 647, 677*L.*, 1179*L.*
D. spumarioides Fr., fruiting on grass and leaves, 1245*L.*, 1246*L.*
Didymium melanospermum (Pers.) Macbr., 1249*L.*
D. squamulosum (A. and S.) Fr., 665, 782, 341*E*
Enteridium Rozeanum (Rost.) Wing, 656*E.*
Fuligo septica (L.) Gmel., 357*E.*, 522, 648, 649, 780, 781.
F. septica var. candida Pers., 1247*L.*
Hemitrichia clavata (Pers.) Rost., 663, 657, 783*E.*, 1240*L.*, 1243*L.*
H. Vesparium (Batsch) Macbr., 678*L.*
Lamproderma violaceum (Fr.) Rost., Victoria Beach, 963*L.*
Lycogala epidendrum (L.) Fr., 345*E.*, 620, 653, 654, 655, Swan River, 1035. Very common.
Mucilago spongiosa (Leys.) Morg., 342*E.*, 767, 775, 779, 1250*L.*
Perichaena corticalis (Batsch) Rost., 426*L.*
Physarum auriscalpium Cke., 344*E.*
P. connatum (Peck) Lister, 651*E.*, 679*L.*, 1244*L.*, 1248*L.* Common.

P. contextum Pers., 680*L*.
P. didermoides (Ach.) Rost., 664, det. Cheesman.
P. nutans Pers. var. leucophaeum Lister, 1243*L*.
P. sinuosum (Bull.) Weinm., 681*L*.
Stemonitis fusca Roth., 304, 644, 618, 683*L*. Common.
Trichia contorta Rost. var. inconspicua Lister, det. *E*. No specimens at Winnipeg.
T. persimilis Karst., 652*E*.
Tubifera ferruginosa Gmel., det. *E*. No specimens at Winnipeg.

BACTERIA.

These few species have been found as plant parasites in Manitoba. Other forms of course occur, but in general bacterial diseases of plants seem to be comparatively indestructive here.

Bacterium translucens J. J. and R., on Hordeum vulgare, 235. Collected and determined by I. L. Conners.
B. translucens var. undulosum S. J. and R. Black chaff is occasional on Triticum aestivum.
Bacillus amylovorus (Burr.) de Toni, on Pyrus Malus, 1099. Quite abundant in 1921.
B. atrosepticus v. Hall, on Solanum tuberosum, 224. A rather serious disease in wet and cool years. Not abundant in 1921.
B. carotovorus Jones, on celery, cabbage and other vegetables.
Pseudomonas Phaseoli E. F. Sm., on Phaseolus vulgaris, causing some loss, 471, 1084.
P. radicicola (Bet.) Moore, on various legumes, 794, 795; wherever legumes grow.
Bacterial Spot on Sudan grass at Winnipeg (Bacillus Sorghi Burr.?), 1153*D*.

PHYCOMYCETES.

None of the Phycomycetes has been found to cause any particular damage to agricultural crops. *Phytophthora infestans* is conspicuous by its absence.

Albugo Bliti (Biv.) O. Kuntze, on Amaranthus retroflexus, 128.
A. candida (Pers.) O. Kuntze, on Brassica sp., 188; on Raphanus sativus, 170.
A. Tragopogonis (DC.) S. F. G., on Cirsium arvense, Ste. Rose, 1169*D*.
Basidiophora Kellermanii (E. and H.) Wilson, on Iva xanthifolia. Reported by W. P. Fraser at Dauphin and elsewhere.
Cladochytrium Alismatis Buesg., on Alisma subcordata, coll. R. Broadfoot, det. I. L. C.
Empusca Muscae Cohn. On house fly, 356.
Mucor Mucedo (L.) Bref., Winnipeg, A. H. R. B.
M. racemosus Fres., A. H. R. B.
Peronospora effusa (Grev.) Rbh. (?). On Chenopodium album, coll. I. L. C.
P. Trifoliorum de By., on Medicago sativa, Brandon, I. L. C., 1154.
Plasmopora Halstedii (Farl.) Berl. and de Toni, on Ambrosia artemesifolia, Ste. Rose, 1134*D*.
P. obducens Schroet., on Impatiens biflora, Swan River, 1140*D*.
Phycomyces nitens (Agardh) Kunze, A. H. R. B.
Pilobolus longipes van Tiegh., on dung, A. H. R. B.
P. crystallinus (Wigg.) Tode, on dung, A. H. R. B.
Piptocephalis Freseniana de By., A. H. R. B.
Rhizopus nigricans Ehr. Common, sometimes semiparasitic on stored vegetables, etc.
Saprolegnia sp. on fish, etc.
Sporodinia grandis Link, on Lentinus lepideus, I. L. C., 1097.
Synchytrium decipiens Farl., on Amphicarpa monoica, 116, Morris, I. L. C., 109. Common.

ASCOMYCETES.

Saccharomycetales: Saccharomyces sp. in fruits of Prunus sp. (wild plum), 1208. Other "wild" yeasts also occur.
Protodiscales: Exoascus Pruni Fcl., on Prunus spp. 305, 325, Dominion City, 578. Common on plums.
Helvellales: Gyromitra esculenta (Pers.) Fr., Kenora.
Helvella crispa (Scop.) Fr., Gimli, 640, 764.
H. lacunosa Afzel., Russell, 1093.
Leotia lubrica (Scop.) Pers., Kenora, A. H. R. B.
Morchella esculenta (L.) Pers., 322, 393, 444, 439. Common.
M. conica Pers. (probably only a form of M. esculenta); Hillside Beach, 411
M. crassipes (Vent.) Pers., 788; Hillside Beach, 410; Minaki.
Spathularia clavata (Schaeff.) Sacc., Minaki, A. H. R. B.
Verpa conica (Mill.) Swartz, Hillside Beach, 409.
Pezizales: Ascobolus immersus Pers., on dung, Winnipeg, A. H. R. B.
Cenangium furfuraceum (Roth) de Not., 734*B*.
C. populneum (Pers.) Rehm, 919*S*.
Chlorosplenium aeruginosum (Oed.) de Not., Shoal Lake S.E. Man., I. L. C., 432; Kenora, 551, 711.
Coryne? sp., near Kenora, 911*S*.
Helotium citrinum (Hedw.) Fr., 384*S*., 407*S*., 1167*Ll*., 916, 926; near Kenora, 912*S*.
Lachnea scutellata (L.) Gill., Kenora, A. H. R. B.
Mollisia cinerea (Batsch) Karst., 401*S*., 420*S*.
Orbilia sp., 910*S*.
Peziza aurantia Muller, Minaki, 863.
P. badia Pers.? Hillside Beach, 412.
P. vesiculosa Bull., 363, 765.
Pseudospeziza Medicaginis (Lib.) Sacc. on Medicago sativa (cult.), 296; Brandon I. L. C., 1155; Swan River, 485.
Sclerotinia libertiana Fcl. on carrots, parsnips and other vegetables. What is considered to be this species has also been collected on Helianthus annuus (cult.), 609, causing a serious stem rot, and on Iva xanthifolia, 102, Cirsium arvense, Helianthus tuberosus, and Sonchus arvense.
Phacidiales: Propolis faginea (Schrad.) Karst., near Kenora, 913*S*.
Rhytisma salicinum (Pers.) Fr., on Salix sp., 90; Gilbert Plains, 1061.
Hysteriales: Hysterographium Fraxini (Pers.) de Not., on Ash wood, 1101*Br*.
Aspergillales: Aspergillus herbariorum (Wigg.) Fisch. Common.
Penicillium spp. The usual blue moulds on various substances.
Perisporiales: Dimerosporium Collinsii (Schw.) Thuem., on Amelanchier alnifolia, 820. Common.
Erysiphe Cichoracearum DC., on Helianthus annuus (cult.), 307; on Ambrosia trifida, Morris, I. L. C., 103.
E. Galeopsidis DC., on Stachys sp., Ste. Rose, 1070.
E. Graminis DC., on Secale cereale, 135. Not serious.
E. Polygoni DC., on Polygonum aviculare, 174, 300; Virden, 289; Swan River, 477; on Pisum sativum (cult.), 1087.
Microsphaera Alni (Wallr.) Wint., on Quercus macrocarpus, J. J. Christensen and G. R. B., 308.
M. diffusa Cke. and Pk. On Lathyrus odoratus, 288. Common.
Podosphaera Oxyacanthae (DC.) de By., on Prunus pumila, Dauphin, F. W. Brodrick, 1175, det. I. L. C.
Sphaerotheca Humuli (DC.) Burr. var. fuligina (Schl.) Salm., on Viola (cult. pansy), 1189; on Taraxacum officinale, Swan River, 491.
Uncinula Salicis (DC.) Wint., on Salix spp. and Populus spp. 148; Virden, 292; Grand Beach, 183; Victoria Beach, 1091.
Hypocreales: Claviceps purpurea (Fr.) Tul., on Agropyron tenerum, Bromus inermis, Calamagrostis canadensis, Elymus canadensis, E. innovatus, Panicularia grandis, Secale cereale, Triticum aestivum, 119, 118, 197, 269; I. L. C., 152, F. J. Higham, 124; Deloraine, 111; Clandeboye,

V. W. Jackson, 1197; Roblin (W. Rae); common and often destructive to wild grasses, common on rye.

Gibberella Saubinetii (D. and M.) Sacc. Fusarium stage on Triticum aestivum, W. H. Mackie Aug. 1920, 374. Quite common in 1921.

Hypomyces lactifluorum (Schw.) Tul. On Lactarius piperatus, L. spp., 333 581, Gimli, 582, Minaki, 786. Very common.

Nectria cinnabarina (Tode) Fr. On Prunus spp., 395; Stony Mountain, 891; Swan River, 1032.

N. episphaeria (Tode) Fr., near Kenora, 914*S*.

N. Peziza (Tode) Fr., St Charles, 949*S*.

Dothidiales: Phyllachora graminis (Pers.) Fcl., on Elymus virginicus, E. canadensis, 72; Neepawa, I. L. C., 108.

Plowrightia morbosa (Schw.) Sacc., on Prunus spp., Virden, 287; Stony Mountain, 892; Swan River, 1033. Very common, and often destructive on wild plums, etc.

Sphaeriales: Anthostoma adustum (C. and P.) Sacc., on old wood, 1168*Br*.

Daldinia concentrica (Bolt.) Ces., on wood, 231, 327, 842, 438; Swan River, 1025.

Didymosphaeria manitobiensis Ell. and Ev., on Rubus (probably R. strigosus), coll. J. Dearness on banks of little Saskatchewan River, Oct. 3, 1891. Reference in N.A. Pyrenomycetes, p. 732. Specimen at Ottawa, from original collection.

Diatrype spp., 948*Br*., 423*Br*.

Gnomonia ulmea (Schw.) Thuem. Conidial stage on Ulmus leaves, J. J. Christensen and G. R. B., 315*D*.

Gnomoniella Coryli (Batsch) Sacc., on Corylus americanus leaves, 179.

Hypoxylon commutatum Nits., on old wood, 947*Br*.

H. fuscum (Pers.) Fr., on old wood, 733*B*., 954*S*.

H. Morsei B. and C., on wood, I. L. C. and G. R. B., 425*Br*.

H. rubigninosum (Pers.) Fr., 739*B*.

Lasiosphaeria strigosa (Alb. and Schw.) Sacc., on wood, 421*S*.

Physalospora Cydoniae Arnaud, Sphaeropsis stage on leaves of Pyrus malus, Morden, coll. A. V. Mitchener, 1050 det. H. T. Güssow. This fungus has not been found to be common on apple.

Valsa translucens de Not., on wood, 937*Br*.

Venturia inaequalis (Cke.) Aderh., on leaves of Pyrus malus, 216, 324, 187. Common but not ordinarily serious on apple.

FUNGI IMPERFECTI.

This list of imperfect fungi is obviously very incomplete. Most of the identifications are by the courtesy of Dr Davis. Few saprophytic forms have been collected.

Alternaria Solani (E. and M.) Jones and Grout, on potato leaves, Gilbert Plains, 1062; common over Manitoba in 1921 but not serious.

Asteroma Gentianae Fcl., on Dasystephana (Gentiana) Andrewsii, 1138*D*. Dr Davis reports that this fungus has been confused with Phyllosticta (Depazea, Leptothyrium) gentianaecola.

Botrytis Paeoniae Oud., on Paeony (cult.), 89. Sometimes injurious.

Cephalothecium roseum Cda., on citron fruit, 298; on Prunus fruit, Swan River, 1074; on Lentinus, 1098.

Cercospora althaeina Sacc., on cultivated hollyhock, 1132*D*.

C. avicularis Wint., on Polygonum aviculare, Lazare, 1128*D*.

C. dubia (Reiss) Wint. (C. Chenopodii Fres.), on Chenopodium album, Carberry, I. L. C., 1157*D*.

C. manitobana J. J. Davis, sp. nov. Spots brown, subcircular, 1–5 mm. in diameter above, less distinct below; conidiophores hypophyllous, fasciculate, fuligenous, straight or incurved or somewhat undulate, simple, sometimes septate, more or less nodulose, 35–60 × 3–4 μ; conidia hyaline, obclavate, straight, becoming 1-septate, 50–63 × 4–6 μ.

On leaves of Shepherdia argentea, Gilbert Plains, Manitoba, coll. July 27, 1921, G. R. Bisby, No. 1125. Type in J. J. Davis' collections, co-type at Man. Agr. College. The trichomes give a somewhat cinereous appearance to the spots.

C. rhoina C. and E., on Rhus Toxicodendron, Thunder Hill, 1136*D*.

Cladosporium subsessile Ell. and Barth., on Populus leaves, 316*D*. Common.

Colletotrichum salmonicolor O'Gara, on stems of Asclepias sp., 318*D*.

Cylindrosporium Padi Karst. (Coccomyces), on leaves of Prunus, 311; Eden, 459.

Cystospora chrysosperma (Pers.) Fr. (Valsa sordida Nke.?), on Populus, J. F. Higham, 446.

Darluca filum (Biv.) Cast., on sori of rusts. Common, especially on telia late in the season.

Discosia artocreas Fr. (?), on Rubus triflorus, 374*D*.

Fusarium conglutinans callistaphi Beach, on Aster (cult.) causing wilt. Common. The fungus was not fully determined as to species but is probably the above.

F. discolor sulphureum Schl., on potato tubers, causing rot. A number of isolations indicated that this is the commonest Fusarium in rotted potatoes in Manitoba.

F. Lini Bolley, on flax (cult.). Not common; definite record only from Winnipeg.

F. oxysporum Schl., on potato. Wilt of potatoes in Manitoba was found, so far as isolations were made, to be caused by this Fusarium.

Haplosporella diatrypoides E. and B.(?), 392*B*.

Helminthosporium gramineum (Rab.) Erik., on barley, 159, 167, Ste. Rose, 1010. Common and sometimes destructive.

H. sativum P. K. and B., on barley; Swan River, 495; everywhere in Manitoba causing considerable injury.

H. teres Sacc., on oats and barley, quite common but not found to be serious.

Phyllosticta livida E. and E., on Quercus macrocarpa, J. J. Christensen and G. R. B., 314*D*.

Ramularia Tulasnei Sacc. (apparently), on cult. strawberry, 123*D*.

R. Urticae Ces., on nettle, I. L. C. and G. R. B., 1191*D*.

Septoria conspicua E. and M., on Steironema ciliata, Ste. Rose, 1139*D*.

S. Convolvuli Desm., on Convolvulus sepium, Emerson, I. L. C., 1176*D*.

S. flagellifera E. and E., on Pisum sativum (cult.), 1150*D*.

S. lactucicola E. and M., on Lactuca sp. 317*D*. The same or a similar fungus also on Sonchus arvense.

S. musiva Pk., on Populus balsamifera, I. L. C., 1172*D*.

S. Oenotherae West, on Oenothera biennis, Gilbert Plains, 1126*D*.

S. ribis Desm., on Ribes (cult. gooseberry), 1194, 1195.

S. Sicyi Pk. (S. Brencklei Sacc.), on Micrampelis lobata, Morris, I. L. C., 313*D*.

S. Symphoricarpi E. and E., on Symphoricarpos sp., Morris, I. L. C., 319*D*.

Trichoderma lignorum (Tode) Harz, has been found.

Vermicularia (?; immature), on Smilax herbacea, 1130*D*.

Verticillium albo-atrum McA. Has been observed on rotting potato tubers.

BASIDIOMYCETES.

USTILAGINALES.

The writers have made no extended search for smuts in Manitoba, and this list includes principally conspicuous economic forms. The range of certain species is, however, extended. W. P. Fraser and I. L. Conners have helped in preparing this list.

Entyloma compositarum Farl., on Ambrosia trifida, Morris, I. L. C., 320*D*.

E. Menispermi Farl. and Trel., on Menispermum canadense, I. L. C., 194*D*.

Sorosporium Syntherismae (Peck) Farl., on Panicum milaceum, Keyes, 150*F*.

Sphacelotheca Sorghi (Link) Clinton, on Sorghum vulgare, 433.

Tilletia laevis Kuehn, on Triticum aestivum, listed by Clinton in N. A. Flora, VII, 48, 1906. This is the only smut from Manitoba listed in that work. The only bunt of wheat the writers have found is caused by T. Tritici; but T. laevis may also still occur in the Province.

T. Tritici (Bjerk.) Wint., on Triticum aestivum, 157. This smut is widespread over Manitoba, although not serious because of the common practice of treating seed wheat.

Urocystis Anemones (Pers.) Wint., on Pulsatilla patens, Brandon, W. P. F. and I. L. C., 380; also collected by Conners at Carberry.

U. occulta (Wallr.) Rab., on Secale cereale, V. W. Jackson, 299. Found by Prof. Jackson on volunteer rye beside the Biology Building, M. A. C.; also reported on the plots at the M. A. C., Winnipeg; not found in fields throughout the Province.

Ustilago Agropyri (?) on Agropyron tenerum, V. W. Jackson, 137. Common and more or less injurious to this grass.

U. anomala (J. Kunze) Wint., on anthers of Polygonum (Tiniaria) cilinode, A. H. R. B., Minaki.

U. Avenae (Pers.) Jens., on Avena sativa, 172, 310, Ste. Rose, 1011; Lonely Lake, 1072. Common and rather destructive to oats.

U. Hordei (Pers.) Kell. and Swingle, on Hordeum vulgare, Portage la Prairie, I. L. C., 107; Gilbert Plains, 1020. Common but does not cause much loss.

U. hypodytes (Schl.) Fries, on Stipa viridula, Rapid City, I. L. C., 173*F*.

U. levis (K. and S.) Magn., on Avena sativa, 309. Not very common.

U. Lorentziana Thuem., on Hordeum jubatum, Boissevain, I. L. C., 182*F*.

U. neglecta Niessl., on Chaetochloa glauca, 297.

U. striaeformis (West.) Niessl., on Beckmania erucaeformis, I. L. C. and H. Groh., 1088*J*. Prof. H. S. Jackson reports that this is the first time he has seen a smut on this host, but that the smut agrees with U. striaeformis though there may be strains.

U. Tritici (Pers.) Rostr., on Triticum aestivum, 176, 180, Oakville, V. W. Jackson, 302; Binscarth, 472; Gilbert Plains, 1066. Common, sometimes causing 10 % loss of wheat.

U. Zeae (Beckm.) Unger, on Zea Mays, Glenora, 358. Very prevalent in 1921.

U. sp. on Phragmites Phragmites. Delta, V. W. Jackson, 1089*J*. H. S. Jackson reports that this may possibly be U. mirabilis Sorokin, heretofore known only from Russia.

Uredinales.

List compiled with the assistance of W. P. Fraser and I. L. Conners.

The number of rusts in Manitoba is necessarily somewhat limited because of the short growing season, the relatively small range of hosts, and the absence of marked variation throughout the province in elevation, precipitation, etc.

The 80 species here listed fall in 19 genera. Only some eight species (five Puccinia, two Polythelis, one Nyssopsora) are short cycled (telia only or pycnia and telia).

The North American Flora (vol. VII) has in general been followed, except that Puccinia and Uromyces names are used.

Aecidium Allenii Clinton, I on Eleagnus argentea, Russell 1002. Probably a stage of Puccinia Rhamni.

Calyptospora columnaris (Alb. and Schw.) Kuehn, III on Vaccinium sp., Minaki.

Coleosporium Solidaginis (Schw.) Thuem., II on Solidago spp. 149, Swan River Valley, 476, 481; Ste. Rose du Lac, 1058; Lonely Lake, 1073; Victoria Beach, 1086; on Aster spp. 146, 1083, Grand Beach, 146; on cultivated asters, 1187; on Doellingeria sp., Lonely Lake, 1056. The mycelium of this rust overwinters in the perennial parts of the plants; aecia have not been found here.

Cronartium Comandrae Peck, II, III on Comandra pallida, Victoria Beach; V. W. Jackson, 1090; common.

Earlea speciosa (Fries) Arth., on Rosa spp., Brandon and Oak Lake, W. P. F.; Eden, 461; Morris, I. L. C., 127; common.

Gymnoconia interstitialis (Schl.) Lagerh., I on Rubus triflorus, Ochre River, V. W. Jackson, 236; Eden, 452. This interesting rust (the longer cycle form) occurs commonly in northern regions. Germination of the aeciospores of the Eden collection showed that they produced germ tubes.

Gymnosporangium cornutum (Pers.) Arth., I on Sorbus americana, Minaki, 611.

G. germinale (Schw.) Kern., I on Crataegus sp., 218. Not uncommon.

G. juvenescens Kern., I on Amelanchier alnifolia, 75, 199, 247*J*.; Eden, 458. Collected also at Brandon and Rapid City, I. L. C.; III on Juniperus horizontalis, Millwood, 497. Frequently found on Amelanchier.

Melampsora Bigelowii Thuem., on Salix spp., Gilbert Plains, 1016; common throughout the Province; collected by V. W. Jackson along the Hudson Bay Railway, 241. "Overwinters in buds and twigs, the uredinia sometimes occurring on opening leaves in the spring." W. P. F.

M. Lini (Schm.) Desmaz., I, II, III on Linum usitatissimum, 229, 1129. II abundant on volunteer flax, collected as late as Oct. 8, 1920, 284. A rather serious disease of flax in Manitoba. II on Linum Lewisii, Russell, 1006; Baldur, I. L. C., 1147.

Melampsorella elatina (Alb. and Schw.) Arth., I on Abies balsamea, Brandon, I. L. C.; II on Cerastium arvense, Brandon, W. P. F.

Melampsoropsis Pyrolae (DC.) Arth., II, III on Pyrola rotundifolia, W. P. Fraser and V. W. Jackson, 251.

Nyssopsora clavellosa (Berk.) Arth., III on Aralia nudicaulis, 1081; Swan River, 1079.

Phragmidium americanum Diet., on Rosa sp. (cult.), 125; reported also from Brandon. This and the other Phragmidia on roses are referred with some doubt as to specific name.

P. imitans Arth., on Rubus strigosus, Brandon, I. L. C., (III) 226*J*.; (II) 227.

P. montivagum Arth., on Rosa blanda, Virden, 222, Morris, I. L. C. Wild roses as far north as Swan River are abundantly affected with rust. Several collections are only in the aecial stage, and it is not certain to which species they belong.

P. Potentillae (Pers.) P. Karst., I, II, III on Potentilla bipinnatifida, P. pennsylvanica, P. strigosa, P. glabrella, P. spp.; Virden, 130*J*.; Lake Clementi, I. L. C., 178, Reston, 437; Stony Mountain, 434; Millwood, 498; Swan River, 496. Common.

Pileolaria Toxicodendri (Berk. and Rav.) Arth., III on Rhus Toxicodendron, 77*J*.; Brandon, W. P. F.

Polythelis Pulsatillae (Rostr.) Arth., on Pulsatilla ludoviciana, Virden, coll. P. R. Cowan, det. W. P. F.

P. Thalictri (Chev.) Arth., III on Thalictrum venulosum, I. L. C., 1171*F*.

Puccinia abundans (Peck) Jackson, I on Symphoricarpos sp., 214, 79; Russell, 1004; Rapid City, I. L. C.

P. amphigena Dietel. Reported by W. P. F., I on Nemexia lasioneuron, Brandon; and II, III on Calamovilfa longifolia.

P. Andropogonis Schw. (P. pustulata Arth.), I on Comandra pallida, 81.

P. angustata Peck. Reported by W. P. F., I on Mentha canadensis, Brandon, Dauphin; and II, III on Scirpus microcarpus, Brandon. (See Mycol. xi, 130.)

P. Antirrhini Diet. and Holw., II on Antirrhinum majus (cult.), greenhouse, M. A. C. J. F. Higham, Mar. 1920 (first report for Manitoba). During 1920,

it became destructive in gardens around Winnipeg; 73, 131, 195. Probably occurred previous to 1920, but was not noted. Not found in 1921.

P. Asparagi DC., II, III on Asparagus officinalis, 270; Brandon, W. P. F. Not found to be serious.

P. Asperifolii (Pers.) Wettst., II on Secale cereale, I. L. C., 142; V. W. Jackson, 274; Swan River, 474. Common, but not serious on rye.

P. Asteris Duby, III on Aster Novae-Angliae, reported by W. P. F., Brandon.

P. Asterum (Schw.) Kern., I on Solidago rigida, S. spp., Aster spp., Grindelia squarrosa, 76, 295, 294, 211; Brandon, W. P. F.; Morris, I. L. C., 93; Virden, 291; Riding Mountains, 466; Swan River, 488; II, III on Carex scoparia, Brandon, W. P. F.

P. calthaecola Schr., I, II, III on Caltha palustris, Dauphin, W. P. F.

P. Cicutae Thuem., on Cicuta maculata, Brandon, W. P. F.

P. Cirsii Lasch, on Carduus Flodmani, Brandon, W. P. F.

P. Clematidis (DC.) Lagerh. (including P. Agropyri); I on Anemone canadensis, A. sp., 163; Morris, I. L. C., 196; Gilbert Plains, 1060; Lazare, 499; Swan River, 482; on Thalictrum dasycarpum, T. venulosum, 126, 71; Morris, I. L. C., 201, Eden, 454; Virden, 290; Swan River, 1076; on Actaea alba, A. rubra, 155*J*., 156, 293; Eden, 455. II, III on Bromus ciliatus, Neepawa, I. L. C., 105; Elymus virginicus, 267; E. Macounii, Morris, I. L. C., 210. Also collected by W. P. F. on Agropyron tenerum, A. Richardsonii, A. Smithii, Bromus latiglumis, Elymus canadensis, Hordeum jubatum, Poa arida. A very common rust in Manitoba. For cultures made by Prof. Fraser, see Mycol. XI, 133, 1919. Collections on Bromus are of the P. tomipara type.

P. Distichlidis Ellis and Ev., I on Steironema ciliata, Morris, I. L. C., 124; Brandon, W. P. F.; II, III on Spartina Michauxiana, Waskada, 100; Brandon, W. P. F.

P. Eatoniae Arth., I on Ranunculus abortivus, Riding Mountains near Kelwood, 464. Placed here with some uncertainty, but the distributed aecia suggest this rust.

P. Eleocharidis Arth., I on Eupatorium purpureum, Brandon, W. P. F.; II, III on Eleocharis sp., Brandon, W. P. F.

P. Ellisiana Thuem., I on Viola canadensis, V. sp., 122, 87; II, III on Andropogon furcatus, Brandon, W. P. F.

P. epiphylla (L.) Wettst., II on Poa pratensis, P. sp., V. W. Jackson, 249, 250.

P. graminis Pers. I on Berberis vulgaris, 202, 138, 252; Brandon, 282. II, III on Triticum aestivum, first found during 1920 on June 30th, at Winnipeg; during 1921, on June 27th, at Emerson; thenceforth northward and soon found everywhere. On Hordeum vulgare, 181, 206, 259; on Avena sativa, A. fatua, 145, 204, 258; V. W. Jackson, 273; on Phleum pratense, 161, 275; Swan River, 480; Gilbert Plains, 1067. The II stage evidently lives over winter on timothy, since the rust can be found on timothy before it appears on grains. On Agropyron repens, A. tenerum, A. caninum, A. Smithii, 153, 261, 213, 208, 260, 262; Lyleton, 97; on Hordeum jubatum, 192, 193, 154, 117; Lyleton, 96. On Elymus Macounii, E. canadensis, 160, 278, Morris, I. L. C., 70. On Dactylis glomerata, 263; on Alopecurus pratensis; The Pas, V. W. Jackson, 266; on Festuca elatior, 265. On Beckmannia erucaeformis, Roblin, W. Rae. Also on other hosts. This is by far the worst plant disease in Manitoba.

P. Grossulariae (Schum.) Lagerh. I on Grossularia spp. and Ribes americanum, R. spp., wild and cultivated, 132, 441, Matlock, 133; Morris, I. L. C., 200; Eden, 457; Virden, 286. II and III on Carex spp., Brandon, W. P. F.

P. Helianthi-mollis (Schw.) Jackson, I, II, III on Helianthus annuus (cult.), H. fasciculatis, H. sp., 470, 92, 171, 165; Portage la Prairie, I. L. C., 101; Brandon, I. L. C., 177; Melita, 110; Waskada, 98; Russell, 1007; Dauphin, W. P. F.

P. hemisphaerica (Peck) Ell. and Ev., I, II, III on Lactuca pulchella, 86, 255, 256, 1082; Lazare, 1001; Gilbert Plains, 1064; Thunder Hill, Swan River, 483.

P. hieraciata (Schw.) Jackson (P. patruelis Arth.), I on Lactuca pulchella, Nabalus albus, 86; Morris, I. L. C., 95; Eden, 462; Brandon, W. P. F.; II, III on Carex spp., Brandon, W. P. F.

P. Impatientis (Schw.) Arth., 0, I on Impatiens biflora, 191; Swan River, 492. 1080; Dauphin, W. P. F. Cultured by Prof. Fraser to Hordeum jubatum (Mycol. XI, 131, 1919).

P. Lygodesmiae, Ell. and Ev., on Lygodesmia juncea, Brandon and Virden, W. P. F.

P. Magnusianum Koern., II, III on Phragmites Phragmites, Dauphin, W. P. F.

P. Majanthae (Schum.) Arth. and Holw., I on Vagnera stellata, Unifolium canadense, 80, 83, Brandon, W. P. F.; II, III on Phalaris arundinacea, Brandon, W. P. F.

P. marylandica Lindr., I on Sanicula marylandica, 306; Brandon, W. P. F.

P. Menthae Pers., II on Mentha glabrior, M. canadensis (?), Monarda fistulosa, M. mollis, Gilbert Plains, 1059; Swan River, 486; Brandon, Dauphin, W. P. F.; Waskada, 99; Grand Beach, 162.

P. monoica (Peck) Arth., I on Arabis sp., W. P. F.; II, III on Trisetum spicatum, The Pas, V. W Jackson, 257.

P. montanensis Ellis, II, III on Agropyron Smithii, Elymus canadensis, Brandon, Dauphin, W. P. F.

P. Peckii (De Toni) Kellerm., I on Oenothera biennis, 88, 240; II, III on Carex Sartwelli, Brandon, W. P. F.

P. Polygoni-amphibii Pers., II, III on Polygonum Hartwrightii, P. Muhlenbergii, 143; Gilbert Plains, 1015, 1065; Swan River, 490.

P. Rhamni (Pers.) Wettst. (P. coronata Corda), I on Rhamnus alnifolia, R. cathartica, 136, 203; Morris, I. L. C., 78; Swan River, 484; Brandon, W. P. F.; II, III on Avena sativa, Calamagrostis canadensis, C. Langsdorfii, Beckmannia erucaeformis, Sclerochloa festucacea, Bromus sp., 204, 283; I. L. C., 106, 129; Swan River, 484; Brandon, W. P. F.; The Pas, V. W. Jackson, 281; Grand Beach, 209.

P. rubefaciens Johans., on Galium boreale, Brandon, W. P. F.

P. rubella (Pers.) Arth., I on Rumex mexicanus, R. occidentalis, Dauphin, W. P. F.; II, III on Phragmites Phragmites, Dauphin, W. P. F. (See Mycol. XI, 130, 1919.)

P. Sherardiana Koern., on Malvastrum coccineum (not certain).

P. Sorghi Schw., II, III on Zea Mays, 467, 469. These are the first specimens known to be collected in Manitoba. The rust came to be very abundant in 1921.

P. Stipae Arth., II, III on Stipa comata, W. P. F.

P. substerilis Ellis and Ev., III on Stipa viridula, Rapid City, I. L. C., 113*F*.; Brandon, W. P. F.; common.

P. Taraxaci (Reb.) Plowr., III on Taraxacum officinale, 121, 190, 1085; Gilbert Plains, 1063.

P. triticina Eriks., II, III on Triticum aestivum, 207; Ste. Rose, 1014, 1069; Swan River, 473. Occurred wherever wheat was grown in Manitoba in 1921, and caused considerable loss.

P. universalis Arth., 0, I on Artemisia gnaphaloides, Brandon, W. P. F.; II, III on Carex praegracilis, Brandon, W. P. F.

P. Urticae (Schum.) Lagerh., I on Urtica Lyalli, U. gracilis(?), Morris, I. L. C., 94; Swan River, 1075; Dauphin, W. P. F.; II, III on Carex spp., Brandon, W. P. F.

P. Xanthii Schw., III on Ambrosia trifida, Morris, I. L. C., 104.

P. Ziziae Ell. and Ev., on Zizia aurea, Brandon, I. L. C., 1198.

Pucciniastrum arcticum (Lag.) Tranz., II, III on Rubus triflorus, W. P. F.; V. W. Jackson, G. R. B., 223*J*.

P. pustulatum (Pers.) Diet., II, III on Epilobium adenocaulon, Brandon, W. P. F.

P. Pyrolae (Pers.) Diet., on Pyrola rotundifolia, 364*D*, 84.

Uredinopsis Struthiopteridis Storm., II, III on Onoclea Struthiopteris, 74; I. L. C and G. R. B., 158*J*.; 468. Common.

Uromyces acuminatus Arth., 0, I on Smilacina stellata and II, III on Spartina michauxiana, Brandon, W. P. F.

U. Alopecuri Seym., I on Ranunculus Macounii, R. scleratus, Brandon,

W. P. F., and collected on and cultured to Alopecurus aristulatus (Mycol. XI, 129, 1919). Aecia considered to belong to this rust were collected in the Riding Mountains near Kelwood, 463.

U. Fabae (Pers.) de Bary, I, II, III on Lathyrus ochroleucus; Viola americana, 221; Swan River, 489, 478, 1078; Neepawa, I. L. C., 215; Gilbert Plains, 1019; Brandon, I. L. C., 184.

U. Glycyrrhizae (Rab.) P. Magn., on Glycyrrhiza lepidota, V. W. Jackson, 1137; Swan River, 1077; Morris, I. L. C., 217.

U. Junci (Desm.) Tul., II, III on Juncus balticus, Brandon and Oak Lake, W. P. F.

U. Polygoni (Pers.) Fcl., I, II on Polygonum aviculare, 85, 248.

U. porosus (Peck) Jackson, on Vicia americana, I. L. C., 1095.

U. proeminens (DC.) Pass., II, III on Euphorbia (Chamaesyce) sp., 242.

U. Trifolii (Hedw. f.) Lév., I, II, III on Trifolium repens; T. hybridum, 169, 168, 166, 245; Swan River, 479. Aecia are common and were collected as late as Aug. 24th, 1921, 1096.

Tremellales.

Exidia albida (Huds.) Bref. (?), Kenora.

E. glandulosa (Bull.) Fr., 362, 602; E. C. Stakman and A. H. R. B., 805; Kenora, 570.

Tremella clavarioides, 1162*Ll.*

T. mycetophylla Peck, on Collybia dryophila, coll. A. H. R. B.

Ulocolla foliacea (Pers.) Bref., on Abies balsamea, A. H. R. B.

Dacryomycetales.

Dacryomyces aurantia Schw., Kenora, 557*Ll.*

D. stillatus Fr. (?), 328.

Guepinia spathularia (Schw.) Fr., Kenora, 965.

Agaricales.

Thelephoraceae (including Hypochnaceae):

Aleurodiscus amorphus (Pers.) Rabenh., 20*V.*

A. cerussatus (Bres.) v. H. and L., 26*B.*, 65*B.* First record for North America.

Coniophora cerebella Pers., Kenora, 946*B.*

C. puteana Fr., Manitou, J. A. MacGregor, 1054*Ll.*

C. suffocata (Pck.) Massee, 925*B.*

Corticium arachnoideum Berk., 743*B*, Stony Mountain, 900*B.*

C. galactinum (Fr.) Burt, 1102*B.*

C. polygonium Fr., 394*B.*

C. roseum Pers., 936*B.*, Stony Mountain, 897*B.*

C. salicinum Fr., Shoal Lake, I. L. C., 429*B.*

C. vagum B. and C. Extremely abundant in the Rhizoctonia stage on potatoes throughout the agricultural areas of Manitoba, causing much damage. Also on other hosts, as sweet pea (Dauphin, 91).

C. vellereum E. and C., 720*B.*

Cyphella Tiliae (Peck) Cooke, 730*B.*

Eichleriella spinulosa (B. and C.) Burt, Swan River, 1048*B.*

Hymenochaete cinnamonea (Pers.) Bres., 31*V.*, 66, 731, 732*B.*, 944*B.*

H. Curtisii (Berk.) Marg., 736*B*

H. rubiginosa (Dicks.) Lév., 748*B.* (resupinate).

H. tabacina (Sow.) Lév., 567*B.*

Hypochnus chalybaeus (Pers.) Bres., 1163*B.*

H. coriarius (Peck) Burt, coll. I. L. C. and G. R. B., 1215*W.*

H. fumosus Fr. (Corticium sulphureum Pers.), 1217*W.*

H. granulosus (Peck) Burt, 708*B.*

H. spongiosus Schw.?, 1158*B.*

Peniophora cinerea Bull., 10*V.*, 11*V.*, 25*V.*, 821, 878*B.*

P. crassa Burt (prob.), 26*xV.*

P. gigantea (Fr.) Burt, 28*V*., 49*V*.
P. laevis (Fr.) Burt, 744*B*.
Stereum cinerascens Schw., 63*B*., 740*B*., 371, 945*B*., 1118*B*.
S. fasciatum Schw., 746*B*., 825*B*.
S. frustulosum (Pers.) Fr., 955*B*., 956*B*.
S. fuscum (Schrad.) Quél. (S. bicolor Pers.), 741*B*., 601*B*., 1234*W*., 827*B*.; Victoria Beach, 909*B*.; Shoal Lake, I. L. C., 427*B*.
S. gausapatum Fr., 34*V*., 1235*W*., 880*B*., 1105*B*., 721*B*.
S. purpureum Pers., 1231*W*., 933*B*., 938*B*., 508*B*., 722*B*., 728*B*., 826*B*.
S. rugum Fr., 24*V*., 367, 500; Ethelbert, R. Pidruchney, 398; Swan River, 1028. Very common on fallen poplar branches.
S. versiforme B. and C. (Peniophora Ellisii Mass.), 1216*W*.
Thelephora laciniata Pers. (?), Minaki.
Clavariaceae: Calocera viscosa (Pers.) Fr., Kenora.
Clavaria abietina Fr., or C. flaccida Fr., 1160*Ll*.
C. cinerea Bull., 1159*Ll*.
C. formosa Fr., Victoria Beach.
C. pistillaris Fr., Kenora, 587, 797.
C. pyxidata Fr., Gimli, R. Hiebert, 628; Swan River, 1044; Russell; Gimli.
C. sp. (not in Cotton and Wakefield's paper), 1161*Ll*.
Typhula gyrans Fr., 1200*W*.
Hydnaceae: Grandinia spp., 44*V*., 372*V*., 879*B*., 1182*B*.
Hydnum caryophylleum B. and C., 725*B*.
H. coralloides Scop., Gimli; Kenora, 538, 793.
H. ferrugineum Fr. (?), Minaki, 536.
H. imbricatum Fr., Minaki, 577.
H. Kauffmani Peck, 526*Ll*.
H. ochraceum Fr., 959*V*.
H. repandum Fr., Kenora, 563.
H. reticulatum (Banker) Sacc. and Trott (?).
Irpex ambiguus Peck (?), Winnipeg.
Mucronella minutissima Peck, coll. A. H. R. B.
Odontia fimbriata Pers., 726*B*.
O. fusco-atra Fr., Swan River, 1043*Ll*.
Phlebia cinnabarina Schw., 1177*B*
P. strigoso-zonata Schw., 58*V*., 749*B*., 877, 852, 1222*W*.; Minaki, 546
Radulum spp., 1*V*., 723*V*.
Tremellodon gelatinosum (Scop.) Fr., Kenora.
Polyporaceae: It will be observed that Dr Overholts has determined most of the species (those marked *V*.). The vicinity of Winnipeg has been fairly well surveyed for Polypores. The nomenclature used by Overholts has been followed and Polystictus is included under Polyporus.
Daedalea confragosa (Bolt.) Fr., 53*V*., 784, 838*V*.; Kenora, 548.
D. unicolor Bull., 2*V*., 598, 833, 839.
Favolus canadensis Klotz., 336, 555, 442, 1109; Kenora, 796; Swan River, 1031.
Fomes applanatus (Pers.) Wallr., 419; Shoal Lake, H. F. Roberts, 755*W*.; Russell, 1021*V*. and 1023*V*.
F. connatus Weinm. (F. populinus Fr. ?), 61*V*., 752*V*.
F. fomentarius (L.) Gill., 841, 418, 951*V*.; Kenora, 700, 701*V*.; Shoal Lake, H. F. Roberts, 759. Common.
F. fulvus Scop. (?), 49*V*.
F. igniarius Fr. Common on living poplar, willow, ash, and other trees. Often reaches an age of 20 or 30 years or more. Quite destructive to trees. Tests showed that spore-fall in Manitoba occurs during July and August. Often resupinate, 15*V*., 365, 953*V*., 1114, 853; Kenora, 568, 703 and 705; Shoal Lake, H. F. Roberts, 758; Swan River, 1027.
F. pinicola Sw., 33*V*., 845*V*., 950*V*.; Gimli, R. Hiebert, 864; Swan River, 1039*V*.; Dr Overholts considers No. 845 to be a variation from the usual type.

F. (Trametes) scutellatus Schw., Kenora, 709*V.*
Lenzites abietina (Bull.) Fr. (? not certain that this species occurs in N. A., possibly L. saepiaria), 1045*V.*, 588.
L. betulina Fr., 603, 846; Kenora, 548*V.*; Minaki, 573; Gimli.
L. saepiaria Fr. (Trametes protracta Fr. when poroid), 41*V.*, 354, 750, C. W. Lowe, 586; Minaki, 572; Gimli.
L. trabeus (Pers.) Fr. (L. vialis Pk.), 50*V.*
Merulius ambiguus Berk., Shoal Lake, I. L. C., 428*B.*
M. corium Fr., 943*B.*
M. niveus Fr. (?), Kenora, 558*B.*
M. tremellosus (Schrad.) Fr., Kenora, 706*V.*, 542*B.*, Shoal Lake, H. F. Roberts, 829*B.*
Polyporus abietinus Fr., Swan River, 1046*V.*
P. adustus (Willd.) Fr., 5*V.*, 16*V.*, 17*V.*, 517, 834, 38*V.* Very common.
P. albiceps Pk.?, 1100*V.*
P. betulinus Bull., 3*V.*; Kenora, 702; Shoal Lake, H. F. Roberts, 757*W.*, Shoal Lake, I. L. C. (May 24, 1921; previous year's pileus producing spores), 1143*W.*
P. biformis Kl., 927*V.*
P. brumalis (Pers.) Fr., 45*V.*, Kenora, 449, 704; Minaki, 545.
P. chioneus Fr., 876, det. E. C. Stakman.
P. cinnabarinus (Jacq.) Fr., Victoria Beach, 810. Not common.
P. conchifer (Schw.) Fr., 844*B.*
P. cuticularis Bull., 957*V.*, Victoria Beach, 908*V.*
P. dichrous Fr., 13*V.*, 27*V.*, 856, 719*V.*, 1178*V.*; Stony Mountain, 893.
P. elegans (Bull.) Fr., 37*V.*, 824*W.*, 1110; Gilbert Plains, 1051; Swan River, 1034.
P. fumosus (Pers.) Fr. (P. fragrans Pk.), 59*V.*
P. hirsutus Fr., 68*V.*, 785, 875, det. E. C. Stakman, 907*V.*
P. lucidus Fr. (?), Kenora, 801.
P. pergamenus Fr. (including P. subchartaceus Murr.), 7*V.*, 9*V.*, 597, 754*V.*; Shoal Lake, H. F. Roberts, 760; Hillside Beach, 416; Ethelbert, W. N. Pidruchney, 399*V.*, Stony Mountain, 896*V.*; Swan River, 1030. Common.
P. peckianus Cooke (?), 961*V.*
P. perennis (L.) Fr., 823*W.*, 960*V.*; Kenora, 566*aV.*, 905*V.*
P. picipes Fr., 906*V*; Gimli, 904*V.*
P. planellus Murr., 27*xV.*, 1123*V.*, 1121*V.* Quite common in Sept. 1921 at Winnipeg.
P. pubescens Schum. (?), Russell, 1022*V.*
P. spumeus (Sow.) Hornem. (P. occidentalis Murr.?), 935*V.*
P. squamosus Pers., small form, 14*V.*
P. sulphureus (Bull.) Fr., 836. Not common.
P. tulipiferus (Schw.) Overh., 4*V.*, 36*V.*, 23*V.*, 30*V.*, 32*V.*, 818, 742, 952*V.*, 1180*V.*; Kenora, 569*V.*; Swan River, 1037*V.* Common and rather variable in appearance.
P. tuberaster Fr. Sclerotia of what is perhaps this fungus (probably the same as Grifola tuckahoe Güssow) are common in fields. See Lloyd, Myc. Note 833.
P. ursinus Lloyd, 753*V.* Not common.
P. velutinus Fr., 6*V.*, 8*V.*, 19*V.*, 751, 501*V.*; Stony Mountain, 894 and 928.
P. versicolor (L.) Fr., 35*V.*, 54*V.*, 831, 832, 840; Stony Mountain, 895*V.*
P. volvatus Peck. On spruce, Ethelbert, W. N. Pidruchney, 400*V.*; Swan River, 1026; Russell. Common northward in Manitoba.
Poria attenuata Peck, 43*V.*, 48*V.*
P. calcea Fr., Swan River, 1036*B.*
P. eupora Karst., 1212*W.*
P. ferruginosa Schrad., 51*V.*, 60*V.*
P. laminata Murr., 12*V.*
P. mutans tenuis Peck (?), 727*V.*
P. ornata Peck, or a similar species, 57*V.*

P. prunicola Murr., 46*V.*
P. Vaillantii Fr., 52*V.*
P. washingtonensis Murr. On deciduous wood, 21*V.*
Solenia anomala Pers., 554*B.*
S. fasciculata Pers. (det. G. F. Atkinson), Winnipeg, A. H. R. B.
Trametes carnea Nees, 39*V.*, 352, 855, 396*V.*, 747*V.*; Gilbert Plains, 1053; Swan River, 1040*V.*; Kenora, 552; Minaki, 543.
T. hispida (Bagl.) Fr., 745*V.*, 902*V.*, 448; Matlock, 348*V.*; Gimli, 903*V.*; Stony Mountain, 890; Gilbert Plains, 1052; Swan River, 1029. Common and variable.
T. rubescens Fr. (Poroid form of Daedalia confragosa (L. O. Overholts, 1120*V.*).)
BOLETACEAE: Boletinus pictus Peck, Kenora, 802.
Boletus flavus Wither., Kenora, Winnipeg.
B. scaber Fr., 717, 1119; seen at Swan River, Russell, Kenora. Common, and the only Boletus found in 1921.
AGARICACEAE: Although over a hundred gill fungi are here listed, very many more occur in Manitoba. Several of these are listed with question-marks, for it is difficult to get determinations of Agarics verified because they decay so rapidly. Dr Kauffman has determined a few. The nomenclature used by Kauffman is followed. The species are arranged by spore colour
Leucosporae: Amanita muscaria Fr., 323, 1122; Kenora, 710; Greenway, C. Vickers Jr., 1196. This poisonous mushroom was common in 1921 in August and September.
A. phalloides Fr., Kenora; no definite record known from Manitoba, but it probably occasionally occurs.
Amanitopsis vaginata Fr., Winnipeg, Victoria Beach, Kenora; common in July and August.
Armillaria mellea Fr., Winnipeg, Kenora.
Cantharellus aurantiacus Fr., Kenora, 556, 561.
C. cibarius Fr., Kenora.
C. umbonatus Fr., Minaki.
Clitocybe gigantea Fr., Gimli.
C. laccata Quél. (Laccaria Berkeley).
C. maxima Fr., Gimli, Minaki.
C. Trogii Sacc. (?), Kenora.
Collybia cirrhata Fr., Gimli, 814; Kenora, 848.
C. confluens Fr., F. J. Higham, 435.
C. dryophila Fr., 332, 447, 1124; Hillside Beach, 415.
C. racemosa Pers. (?), Minaki, 635.
C. tuberosa Fr., Kenora, 816, 847, 849; Gimli.
C. velutipes Fr., Apr. 3rd, 1921, 321; Gimli; Kenora.
Hygrophorus chrysodon Fr., Kenora, 857 and 560.
H. conicus Fr., Gimli.
H. niveus Fr., Gimli.
Lactarius deliciosus Fr. In a squirrel's nest, Treesbank, S. Criddle, 940*K.*, Gimli, Minaki. For other fungi collected by squirrels see also Buller, A. H. R., Trans. Brit. Myc. Soc. VI, 355, 1920.
L. glyciosmus Fr., Minaki.
L. piperatus Fr., Winnipeg, Gimli, commonly parasitized by Hypomyces.
L. rufus Fr., Minaki.
L. torminosus Fr., Gimli. Reported by some to be poisonous.
L. uvidus Fr. ("very probably" *K.*). Another fungus collected by squirrels, Treesbank, S. Criddle, 939*K.* Considered poisonous to man and guinea-pigs, but not to rabbits (Kauffman). Dr Kauffman reports certain other fungi sent him from squirrels' nests to be probably Lactarii
Lentinus lepideus Fr., Ste. Rose, 1009; Deloraine; Selkirk. Everywhere on railway ties; also collected on living Negundo aceroides, I. L. C., 1055*K.*
Lenzites, see Polypores.
Lepiota naucina Fr., 1211.

Marasmius epiphyllus, Fr., 1181*K*.
M. oreades Fr., 843.
M. rotula Fr., 1144*K*.
M. siccus Schw.(?), Winnipeg.
M. urens Fr., det. E. C. Stakman. Reported by some to be poisonous.
Mycena alcalina Fr., Minaki, Kenora.
M. galericulata Fr., 1115; Kenora.
M. pura Fr., Kenora.
Omphalia campanella Fr., Kenora, 562, 716, 860.
O. campanella badipus, Kenora, 799.
O. epichysium Fr.(?), I. L. C., Winnipeg.
Panus rudis Fr., 854; Victoria Beach, 809.
P. stypticus Fr., 502.
Pleurotus circinatus Fr., Winnipeg.
P. ostreatus Fr., 335, 600; Swan River.
P. ulmarius Fr., 347, 585. Common on elms and maples around Winnipeg.
Russula aeruginea Lindbl., I. L. C., 1203.
R. aurantialutea Kauff., from a squirrel's abode, Minaki, Dr C. N. Bell, 931*K*.
R. emetica Fr., 1204; Swan River; Minaki
R. integra Fr., Minaki, Gimli.
R. nitida Fr (?), Gimli.
R. virescens Fr., Kenora.
Schizophyllum commune Fr., 506, 589, 777, 112, 355; E. C. Stakman and A. H. R. B., 804; Swan River, 1024. Very common everywhere.
Trogia crispa Fr., 619; Kenora, 712.
Rhodosporae: Claudopus nidulans Fr., 851; Gimli, 584.
Pluteus cervinus Fr., Winnipeg; Gimli; Kenora, 713.
Volvaria speciosa Fr., Mr Rigby, 337; Gimli.
Ochrosporae: Cortinarius armillatus Fr., Minaki, 571.
C. cinnamomeus Fr.(?), Kenora.
C. mucifluus Fr., Minaki, 541; Kenora, 714.
C. violaceus Fr.(?), Kenora.
Crepidotus herbarum Pk., Swan River, 1104*K*.
C. mollis, Fr., 443.
C. versutus Pk., Gimli.
Flammula sapinea Fr., Gimli.
Galera hypnorum Fr., Pointe du Bois.
G. tenera Fr., Gimli, 642.
Hebeloma sp., Russell.
Inocybe sp., Winnipeg.
Naucoria hamadryas Sacc., Hillside Beach, 414.
N. pediades Fr., 331.
N. semiorbicularis Fr., Winnipeg.
Paxillus involutus Fr.(?), Winnipeg.
P. panuoides Fr., on sawdust, Gimli.
Pholiota adiposa Fr.
P. dura Bolt. (?), St Charles. cf. P. verniflua
P. erinaceella Pk., I. L. C., J. F. Higham, G. R. B., 1103*K*.
P. squarrosa Quél.(?), Gimli, 583. This species may be limited to Europe, according to Kauffman.
P. squarrosoides Pl.(?), Minaki, 576.
Porphrosporae: Hypholoma appendiculatum Fr., Winnipeg, Stony Mountain.
H. fasciculare Fr., Gimli.
H. incertum Pk. var. sylvestris Kauff., 1106.
H. perplexum Pk., Winnipeg.
Psalliota (Agaricus) campestris Fr., bisporous form, C. W. Lowe, 763.
P. campestris Fr., quadisporous form, Gimli.
P. sylvatica Quél. (?), Kenora, 549.
Stropharia epimyces (Pk.) Atk., 882. Det. E. C. Stakman; reported by Kauffman to have been seen by Pennington at Winnipeg.

S. semiglobata Fr., Gimli.
Melanosporae: Anellaria separata Karst., Gimli.
Coprinus atramentarius Fr., 634, 789, C. W. Lowe, 790, 1108.
C. comatus Fr., C. W. Lowe, 787, 792.
C. curtus Kalchbr. Common at Winnipeg.
C. domesticus Fr., Winnipeg.
C. ephemerus Fr., Winnipeg.
C. Hendersonii Berk. On horse-dung, Winnipeg.
C. lagopus Fr. (C. fimetarius Fr.), Winnipeg.
C. micaceus Fr., 330; common.
C. narcoticus Fr., Winnipeg.
C. niveus Fr., Winnipeg.
C. plicatilis Fr., 835.
C. stercorarius Fr., 815, 817, 887, 888.
C. sterquilinus Fr., R. Hiebert, 627.
Gomphidius glutinosus Fr., Kenora, 798.
G. viscidus Fr., Kenora 550; Minaki, 575.
Panaeolus campanulatus Fr., 440, 436; Hillside Beach, 413; Thunder Hill.
P. papilionaceus Fr., 1201.
P. solidipes Peck, Winnipeg, A. H. R. B.; Sturgeon Creek, C. W. Lowe, 791.
Psathyra persimplex Britz., 1209.
Psathyrella disseminata Fr., 424, 1107.
P. crenata (Lasch.) Fr.(?), 1205.

Phallales.

Dictyophora Ravenelii (B. and C.) Burt, Kenora, 613.

Lycoperdales.

Bovista plumbea Pers., 378*Ll.*; Gimli, 529*Ll.*; Kenora, 884.
Calvatia coelata (Bull.) Morg. (?), Gimli, 533.
C. gigantea (Batsch) Morg., 339; Gimli.
C. pachyderma (Peck) Morg. (?), Gimli, 535.
Geaster coronatus Schaeff., Kenora, 813*Ll.* Very similar to L. minimus.
H. hygrometricus Pers., Victoria Beach, 812*Ll.*
G. rufescens Schm., 599*Ll.*
Lycoperdon cepaeforme Bull., 811*Ll.*, Gimli, 531*Ll.*
L. gemmatum Batsch, 837*Ll.*
L. piriforme Schaeff., 921*Ll.*, 370*Ll.*; Matlock, 383; Eden, 450; Shoal Lake, H. F. Roberts, 828*Ll.*
L. polytrichum Lloyd, Point du Bois, 918*Ll.*
L. Wrightii Berk., Gimli, 530*Ll.*
Mycenastrum corium Desvaux, 379*Ll.*
Secotium acuminatum Mont., Gimli, 624; Sturgeon Creek, 625.
Sphaerobolus stellatus Tod., Kenora.
Nidulariales: Crucibulum vulgare Tul., Kenora, 929.
Cyathus striatus (Huds.) Hoffm., 596, 349; Kenora.
C. vernicosus (Bull.) DC., 338.
Nidularia pisiformis (Roth.) Finl., Kenora, 964.
Uncertain: Ptychogaster subiculoides, named by Lloyd from 1164 sent him. Quite common in 1921, but never developed into anything definite.

LICHENS.

The majority of the species listed for convenience here were collected by John Macoun, principally from Lake Winnipegosis and other points north of the agricultural area of Manitoba, and listed in his paper "Catalogue of Canadian Plants. Part VII. Lichens and Hepaticae." Geol. Survey of Can. 1902, pp. 49–180. Macoun lists 614 lichens for Canada, and Fink (Minn. Bot.

Stud. III, 167–236, 1903) records 310 from the northern boundary of Minnesota (most of which naturally occur also in Manitoba); it is obvious that this list covers but a small fraction of the forms which occur in Manitoba.

The letter "*M.*" after a record indicates that the species is listed by Macoun. Where the names he used differ from those used by Smith (A Monograph of the British Lichens, 1918 and 1911), the name in Macoun's list is included in parenthesis.

Alectoria jubata (L.) Ach. (Bryopogon jubata var. implexa, Fr.), Porcupine Mts., *M.*

Arthonia patellulata Nyl., on aspen poplar trees, Moose Mt., July 3rd, 1880, *M.*

A. radiata var. Swartziana (Ach.) Sydow (A. Swartziana Ach.), on balsam fir, Lake Winnipegosis, *M.*

Biatorella moriformis (Ach.) Th. Fr. (Biatora moriformis Ach.), on bark and dead wood, Lakes Manitoba and Winnipegosis, July 2nd, 1881, *M.* Reported in Macoun's list only from Manitoba.

Bilimbia sabuletorum B. and R. (Biatora hypnophila (Turn.) Tuckerm.), on moss along Lake Winnipegosis, *M.*

B. sphaeroides (Dicks.) Koerb. (Biatora sphaeroides (Dicks.) Tuckerm.), on moss at base of trees, Red Deer River, Porcupine Mts., *M.*

Cladonia alpestris (L.) Rabenh. (C. sylvatica var. alpestris L.), on Duck Mts., *M.* Fox Lake, Ont., 606.

C. coccifera (L.) Willd., coll. A. H. R. B.

C. crispata Flot. (C. furcata (Huds.) Fr. var. crispata Floerk.), on earth, Red Deer River, Porcupine Mts., *M.*

C. crystatella Tuck., 632; Fox Lake Ont., 605.

C. deformis (L.) Hoffm., on earth, Red Deer River, Porcupine Mts., *M.*

C. fimbriata var. simplex Wainio (var. tubaeformis Fr.), on rotten logs, Lake Winnipegosis, *M.*

C. fimbriata var. radiata Cromb., on the Porcupine Mts., *M.*

C. gracilis (L.) Willd. var. hybrida Schaer., at Lake Winnipegosis, *M.*

C. gracilis var. elongata Fr., on old logs, Red Deer River and Porcupine Mts., *M.* (Perhaps same as preceding.)

C. pyxidata (L.) Hoffm., Red Deer River and Lake Winnipegosis, *M.*, 633.

C. rangiferina (L.) Web., 762. The Reindeer Moss.

C. squamosa Hoffm., Lake Winnipeg (Herb. Hooker), *M.*

C. sylvatica (L.) Hoffm., in woods, Duck Mts., *M.*

C. turgida Hoffm. var. conspicua (Schaer.) Nyl., in woods, Duck Mts., *M.*

Collema tenax (Sw.) Sm., on earth, Otterbourne, *M.*

Evernia prunastri (L.) Ach., on trees, Duck Mts. and Lake Winnipegosis, *M.*

Graphis scripta Ach. var. limitata Schaer., on bark along Lake Winnipegosis, *M.*

Gyalecta lutea (Dicks.) Tuckerm., on spruce bark along Red Deer River, Porcupine Mts., *M.*

Gyrophora polyrrhiza (L.) Krb., Minaki, 626.

Lecanactis premnea Ach. var. chloroconia Tuckerm., on white spruce bark, Swan Lake House, Lake Winnipegosis, *M.*

Lecanora subfusca (L.) Ach. var. allophana Ach., on aspen poplar, Greenwood Twp. (Thos. Walker); on trees along Lake Winnipegosis, *M.*

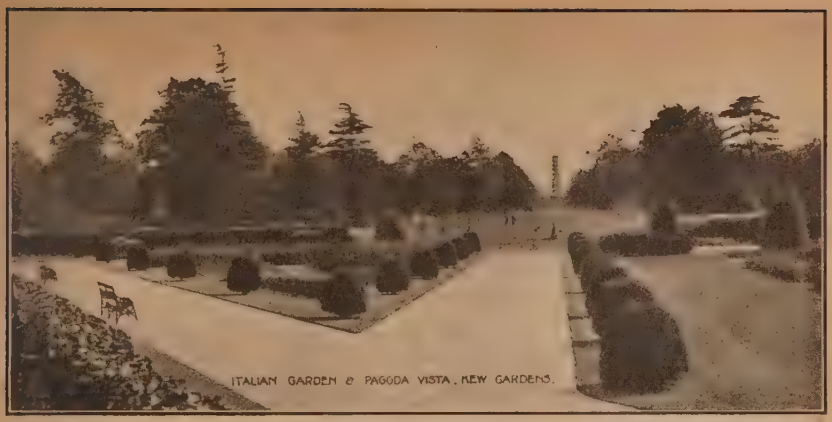
Lecidea enteroleuca Fr. var. achrista Sommerf., on bark of trees along Lake Winnipegosis and on Moose Mts., *M.*

L. parasema Ach. (Buellia parasema Th. Fr.), on bark of paper birch, Red Deer River, Porcupine Mts., *M.*

L. vernalis (L.) Ach. (Biatora vernalis Fr.), on bark of trees, Red Deer River, Porcupine Mts., *M.*

Nephromium resupinatum D. T. and S. ("Nephroma tomentosum (Hoffm.) Koerb."), on trees, Manitoba House, *M.*

Parmelia caperata (L.) Ach., on dead wood, Manitoba House, *M.*
P. saxatilis (L.) Ach., on trees, Red Deer River; collected also by A. H. R. B.
P. sulcata Tayl., on rocks, Fox Lake, Ont., Dr F. C. Bell, 525.
P. tiliacea (Hoffm.) Ach., on rocks, Kenora, 807.
Peltigera aphthosa (L.) Willd., on earth in woods, Duck Mts., *M.*
P. canina (L.) Willd., coll. A. H. R. B.
P. rufescens (Neck.) Hoffm., on earth, Manitoba House, *M.*
Physcia hispida (Schreb.) Tuckerm., on poplar trees, Stony Mt., *M.*
P. orbicularis D. T. and S. (P. obscura (Ehrb.) Nyl.), on trees, Lake Winnipegosis, *M.*
P. stellaris (L.) Nyl., on trees at Winnipeg and Manitoba House, *M.*; C. W. Lowe, 770; common.
Placodium cerinum (Hedw.) Hepp., along Red Deer River, *M.*
Stereocaulon paschale (L.) Fr., on rocks, Kenora, Miss M. G. Rioch, 769; Fox Lake, Ont., 607.
Theloschistes chrysophthalmus (L.) Th. Fr., on trees, Lake Winnipegosis, *M.*
Usnea barbata Web. (U. barbata var. dasypoga Fr.), on trees in woods, Duck Mts., *M.*
U. florida Web. var. hirta Ach. (U. barbata var. hirta Fr.), Manitoba House and Porcupine Mts., *M.*
Xanthoria parietina (L.) Th. Fr. (Theloschistes parietinus Norm.), on stones, Lake Winnipegosis, *M.*; C. W. Lowe, 770.
X. polycarpa (Ehrb.) Oliv. (Theloschistes polycarpus Tuckerm.), on scrub oaks, Greenwood (Thos. Walker); on trunks, Red Deer River, Lake Winnipegosis, *M*



KEW GARDENS

Kew is a suburban village up the Thames from London on the way to Richmond. This quiet village has of course long been in existence; the records date back to a time when it was spelled "Kayhough". For a century the chief attraction at Kew has been the Royal Botanic Gardens. They contain the finest collection of plants in the world. To many thousands of Londoners and others Kew Gardens provide a perennial source of pleasure and profit.

The Gardens cover some four hundred acres. Most of the plantings are arranged in the "English style," i.e., informally and naturally, in contrast to the formal and artificial spacing of plants in vogue in many continental gardens. A visitor is struck upon his first visit by the size and beauty of the grounds, and by the number and splendor of the greenhouses and museums. The landscape architect who laid out the trees and shrubs arranged for a large number of splendid vistas; one unexpectedly encounters long open spaces leading to the pagoda, to a distant greenhouse or group of shrubs, across the lake, up the Thames, or to a church spire in Richmond. Each time one wanders through the grounds he is impressed by some new vista or bit of landscape that he had not seen before, and the view changes from week to week throughout the year. Winter and summer the grounds keep their green carpet of grass.

Despite the fact that London lies about one hundred and forty miles north of Winnipeg, the thermometer never falls far below freezing. As a consequence some outdoor plants may always be in bloom. Throughout last winter there were always winter crocuses in flower; about the first of the year Christmas roses and snowdrops opened; every now and then some alpine plant appeared to suggest that winter in Kew is like spring on a mountain top. By March yellow narcissi sprang up everywhere, and a rapidly changing panorama of early blooming shrubs, trees, and herbs culminated in May in gorgeous expanses of English blue-bell, and in brilliant banks of rhododendrons and azaleas. Throughout spring, summer, and autumn, an endless profusion of blossoms is always to be found. Perhaps the most interesting trees in the Gardens are the Cedars of Lebanon. Since the plants all bear labels, identification is easy. Canada is conspicuously represented by a flag pole of Douglas fir from British Columbia, which rises 215 feet above an eminence in the grounds.

The educational and aesthetic facilities of Kew Gardens are undoubtedly the outstanding features of the place. The greenhouses are arranged so as to give one an idea of tropical, desert, south temperate, and other groups of plants. Museums are devoted to the illustration of economic plants, of kinds of wood, of processes of manufacture of the countless products of the plant kingdom. One cannot look long in Kew without appreciating how much is owed to the sometimes scorned science of botany. One of the most interesting museums is one devoted to paintings of plants and scenery made in all parts of the world, especially the out-of-the-way parts, by the late Miss North.

The rock garden, Japanese garden, systematic plantation, bamboo garden, pinetum, lake, orchid collection, Victoria regia (giant water lily), and many other features must be passed over without an attempt at description. Something should be said, however, of the work Kew is doing and has done.

In the herbarium and library are collections of pressed plants and botanical publications that draw scientific workers from every part of the globe. Kew has played a leading part in systematizing our knowledge of the vegetation of the world. Kew has tested out plants from everywhere; has arranged for the introduction of economic plants into the places they grow best. The "romance of rubber" centers in Kew; were it not for the activity of the Garden officials in introducing rubber plants into India, Ceylon, and elsewhere, rubber might even yet be prohibitive in price, if not actually unattainable in quantity. Kew constantly supplies trained gardeners and scientific workers to all corners of the world.

Everyone who uses plant products owes something to Kew Gardens; everyone who has seen Kew Gardens has seen one of the most beautiful spots in the world.

G.R.B.

OVER THE ISLAND HIGHWAY — AND BACK

Oh it's nice to go a roaming
O'er the lovely Island lane
When the balmy winds of summer
Make all toiling seem in vain!
When the lulling, sleepy breezes
That blow in from off the sea
Puts charm into the hazy days;
The mazy, lazy, crazy days,
Of June in old B.C.

And it's nice to sit a mooning
Near the entrance of your tent
And listen to the murmur —
Of the river seaward bent
And you plan of rising early
To go fishing — yes siree
They are well nigh perfect trolling streams
Those flowing, bowling, rolling streams
June rivers of B.C.

Potato Seed Treatment Tests in Manitoba.

G. R. BISBY, J. F. HIGHAM, H. GROH.

Rhizoctonia is exceedingly common on potatoes in Manitoba. The injury to the sprouts often results in missing hills, and the fungus continues to cause damage throughout the growing season by attacking the roots, stolons, and underground stems. Usually a considerable percentage of the tubers will be found, when dug, to bear black scurf surface blemishes. The prevalence of black scurf on the tubers is often such as to preclude seed certification where a limit of ten per cent. of affected tubers is fixed.

The abundance of Rhizoctonia in Manitoba is undoubtedly largely explainable on the basis of soil temperature. Richards (1) has shown that severe damage to the potato plant by the fungus occurs at soil temperatures below 21°C. When the senior author reached Manitoba in 1920, he at once proceeded to make tests of various seed treatments in the hopes of being able to prevent the disease. Previous experience elsewhere had given results similar to those reported by Howitt (2), and showed that corrosive sublimate was valuable in reducing injury from Rhizoctonia on the growing crop, and in lessening the number of tubers bearing black scurf sclerotia. Three years tests in Manitoba have, however, given results different from any the authors have seen reported, and indicate that the black scurf problem is different here than in many areas.

During 1920 Beauty of Hebron potatoes were treated with solutions of corrosive sublimate, formaldehyde, and copper sulphate. It is unnecessary to list here in detail the results obtained. The results as regards scab were good; an average of 18.3 per cent. of the tubers from untreated seed showed scab, and only an average of 4.6 per cent. of the tubers from treated seed were scabbed. For black scurf the data could not at the time be interpreted; an average of 56.7 per cent. of the tubers from treated seed bore black scurf, and an average of 57.6 per cent. of the tubers from untreated seed were scurfed. Although the results were best with corrosive sublimate (average 46.4 per cent. scurf on progeny of affected and treated tubers), the difference even here was not great. Each treatment plot in 1920 consisted of three rows; two rows of each plot were dug Sept. 1-8, and the third Oct. 8-9. In every case but one the later diggings showed more black scurf than the earlier; the averages of all plots dug Sept. 1-8 was 51.1 per cent. black scurf, and of those dug Oct. 8-9, 58.7 per cent. scurf. The significance of date of digging was, however, not obvious from the 1920 data.

In 1921 a replicated series of treatment plots was planted. The plots were dug from time to time during the autumn. The first check plot (from seed with black scurf, no seed treatment) dug on Aug. 20, gave the surprising result of only 7.5 per cent. black scurf. Table 1 gives the results in full.

It will be seen from Table 1 that seed treatment had practically no influence on the amount of black scurf present; the limiting factor was the date of digging, as shown by the following list:

Dug	Aug.	20	Progeny	bore	7.5	per	cent.	black	scurf.		
"	"	26	"	"	54.0	"	"	"	"		
"	"	30-31	"	"	56.3	"	"	"	"	(Average)	
"	Sept.	1-2	"	"	70.8	"	"	"	"	"	
"	"	6-7	"	"	88.5	"	"	"	"	"	
"	"	8-9	"	"	94.4	"	"	"	"	"	
"	Oct.	13	"	"	93.5	"	"	"	"		

Table 1. Results of treating potatoes at M.A.C. in 1921.

Plot	Seed used	Treatment used	Time Treated	Date Dug	Number Clean	Number Scurfed	Number Scabbed	Total Number	Weight lbs.	Percent Scab	percent Black scurf.
1	B.Scurf	None		Aug.20	181	29	179	387	130†	46.3	7.5
2	B.Scurf	None		Aug.26	61	180	175	333	115	52.6	54.6
3	B.Scurf	None		Oct.13	11	358	183	583	116	47.8	93.5
4	Clean	None		Aug.30	91	155	114	319	117	35.9	48.6
5	Scurf	$CuSo_4$	1:150, 2Hrs	Aug.31	124	147	2	273	104	.7	53.8
6	Scurf	$CuSo_4$	1:150, 1hr	Aug.31	89	196	21	295	113	7.1	66.4
7	Scurf	$CuSo_4$	1:150, ½hr	Sept.1	69	231	10	303	110	3.3	76.2
8	Scurf	$CuSo_4$	1:100, ½hr	Sept.1	88	201	12	294	103	4.1	68.4
9	Scurf	ECOH	1:320, 2hrs	Sept.1	92	207	9	306	126	2.9	67.6
10	Clean	$HgCl_2$	1:1000, ½hr	Sept.2	99	233	3	335	122	.9	69.5
11	Scurf	$HgCl_2$	Ditto. . . .	Sept.2	79	215	3	297	117	1.0	72.4
12	Clean	none	. . . . .	Sept.9	23	300	58	336	122	17.3	89.3
13	Scurf	As 5	. . . . .	Sept.9	8	322	7	335	108	2.1	96.1
14	Scurf	As 6	. . . .	Sept.9	27	329	12	361	115	3.3	91.1
15	Scurf	As 7	. . . . .	Sept.9	5	342	9	348	118	2.6	98.3
16	Scurf	As 8	. . . . .	Sept.8	12	313	28	320	100	8.7	97.8
17	Scurf	As 9	. . . . .	Sept.8	21	353	37	376	124	9.8	93.9
18	Clean	As 10	. . . . .	Sept.7	41	312	17	362	114	4.7	86.2
19	Scurf	As 11	. . . . .	Sept.6	51	286	16	343	108	4.6	83.4
20	Scurf	None		Sept.6	3	307	150	320	101¶	46.9	95.9

‡ The total is not necessarily the sum of preceeding columns, because some tubers bore both scab and black scurf.

† Border row. ¶ Not a border row.

Some scab present on seed used. Rows uniform in length and number of hills. Early Ohio variety used, treated on May 7, cut and planted on May 16 and 17.

This shows clearly that in 1921 black scurf developed rapidly on the potato tubers, apparently beginning about the middle of August and reaching a maximum about Sept. 9.

Good results were again evident in the case of scab, and were unaffected by date of digging. The following summary may be made:

Average per cent. scab from affected		untreated tubers,	4	plots	48.4
" " "	partly clean	" "	2	plots	26.6
" " "	all treated tubers		14	plots	4.0

The yield results may be compared in Table 1. The treatment did not exert a marked effect upon yield: the lowest yield was obtained for copper sulphate 1:100, and the next lowest for copper sulphate 1:150 for two hours. The best yield was obtained from seed treated with formaldehyde, the next best from clean tubers planted without treatment; followed by the yield from seed treated with corrosive sublimate. The differences are not great. Lessened yield may result from treated sprouted tubers, as has been noted in various other regions, but proper treatment of unsprouted scurfed seed may be expected to increase the yield somewhat.

Considerable field and laboratory experimentation at the Manitoba Agricultural College demonstrates that copper sulphate is not safe for treating in the spring. The well known toxicity of this poison to algæ and certain fungi, and its comparative cheapness, made it appear that it might be valuable for black scurf and scab treatment. It was found, however, that for a number of reasons this chemical is unsatisfactory. When dissolved in any but the purest water, part of the copper is precipitated out, and the strength of the solution is therefore uncertain. When 4 grams of $CuSO_4$ were dissolved in 1000 cc. tap water, a chemical test by Dr. C. B. Clevenger gave only 3.432 gms. in solution; in the case of water from the Red River, only 3.354 gms. remained of the 4; in water from a well more than a quarter of the copper was precipitated out, leaving only 2,925 gms. in solution of the 4 gms. put in. Tests made by treating tubers bearing sclerotia with $CuSO_4$ solutions of various strengths in tap water gave the following results: the sclerotia on potatoes were not killed by a two hour treatment in solutions of the strengths 1:1000, 1:750, 1:250, and were not all killed at a strength of 1:175 for two hours. At a strength of 1:100 for one-half hour no sclerotia were found to grow when placed on culture media. In six tests of $HgCl_2$ 1:1000, growth of sclerotia was found in only one case. The laboratory and field tests showed that the strength of

$CuSO_4$ solution required to kill sclerotia is such as will frequently injure the eyes of tubers.

During 1922 tests were made of planting as well as harvesting tubers at different dates. Treated and untreated tubers were planted May 5, 15, 22, 26, 29; June 1, 10, 20, and July 1, and some of each were dug Sept. 1, 10, 20; Oct. 4 and 13. In 1922 again there was no difference to be noticed between the amounts of black scurf on the progeny of treated and of untreated seed tubers. All potatoes dug Sept. 1 showed an average of 39 per cent. black scurf, those dug Sept. 10, 43.3 per cent; Sept. 20, 61.3 per cent.; Oct. 4, 71.4 per cent; Oct. 13, 82.8 per cent. The average per cent. of black scurf on potatoes planted May 5 and dug at different dates was 73; May 15, 80; May 22-26, 76; May 29 - June 1, 81; June 10, 61.2; June 20, 39.2; July 1, 42.5. In 1922, therefore, potatoes were already considerably affected with black scurf by Sept. 1. Black scurf could not be avoided this year by late planting, since the date of planting at which reduction in black scurf became evident was too late to be practicable.

In all the above data, the figures for percentage. of black scurf were obtained by washing the tubers with water and counting as scurfed all tubers which showed sclerotia when damp, since the sclerotia are much more evident on damp than on dry tubers. The figures for black scurf are therefore higher than they would be if a count were made of dry and more or less dirty tubers in a bin. It may also be remarked that the sclerotia tend to increase in size and conspicuousness as well as in numbers on tubers left in the soil.

Three years' test at Winnipeg allow the following conclusions to be drawn for these years and the conditions of the experiments:

1. Sclerotia of Rhizoctonia developed in about as great numbers on the progeny of treated as of untreated tubers. 2. Tubers dug early (late August to the first of September) had fewer sclerotia than those left longer in the soil. 3. Black scurf could not be practicably avoided during 1922 by late planting. 4. Seed treatment was found during the two years in which counts were made, to reduce the amount of scab. 5. A slight increase in yield was obtained from treating scurfed tubers with formaldehyde or corrosive sublimate. 6. Copper sulphate was not found to be dependable or safe for seed treatment.

Manitoba potato growers may be able to avoid some of the trouble from black scurf on potatoes by digging as early as is practicable. Seed treatment was valuable for scab at Winnipeg and might have reduced the amount of black scurf in certain other areas or in other soils of the province. The treatment of seed tubers, if unsprouted, is a sound sanitary measure, and the writers would apply it at least to the plots grown for seed. But the fact remains that soil infestation with Rhizoctonia under Manitoba conditions is such as to render the tubers extremely liable to considerable infection with black scurf, an infection which cannot be avoided by seed treatment. Fortunately, good yields are obtained in the Province in spite of Rhizoctonia. Black scurf does, however, make the certification of potatoes rather difficult in Manitoba.

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EXTENSION BULLETIN No. 66

Manitoba Potato Diseases And Their Control

Fig. 1. Leaf Roll in rather severe form. See page 3.

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Published by authority of Hon. Neil Cameron, Minister of Agriculture and Immigration

Manitoba Potato Diseases and their Control

Manitoba, in many respects, is favorably situated for potato growing. It is true that dry weather conditions may reduce the crop some years in certain areas, and that frost may cause damage, especially in the north. The potato, however, is a plant which thrives under the comparatively cool conditions that may be expected in Manitoba, and the dry weather conditions have the advantage of preventing late blight and certain other serious potato diseases.

During the past few years it has become evident to many growers, to the Manitoba Agricultural College and to the Extension Service that certain diseases, particularly leaf roll and mosaic, had been introduced into the province and were causing a great deal of damage. In fact, it may conservatively be estimated that Manitoba would produce a million bushels of potatoes more per year if it were not for the ravages of potato diseases. Considerable of this loss can be prevented.

For several years Prof. V. W. Jackson has been making observations on potato diseases and urging the use of methods of eliminating certain of these troubles. Mr. Paul Murphy, then of the Dominion Department of Agriculture, visited the province in 1918 and called attention to the seriousness of leaf roll and certain other little-known diseases. During the past three years a number of observations and experiments have been performed, and it is believed that many growers and others would welcome descriptions of the potato diseases which occur and suggestions as to methods of preventing them. It should be emphasized at the outset that the use or introduction of healthy, certified seed, and the maintenance of proper seed plots, cultural practices, etc., as advised and put into practice by the Horticultural Department and by the Extension Service, have been, and will be, of very great value in improving the yield and quality of potatoes in Manitoba. There is, however, still required a more general understanding of the potato diseases which occur, and of certain control measures, in order to continue the progress already made.

Many potato diseases are caused by parasitic fungi, which are minute, living organisms growing on or in, and at the expense of, various portions of the plant. Some are caused by bacteria, which are similar to fungi, and some, such as frost injury and black-heart, are caused by weather, soil, or storage conditions. No known potato disease will injure persons or animals.

In order to be able more easily to determine the several diseases which may attack the potato in Manitoba, the key following should be of value. One can follow down the key and ordinarily settle doubtful points by consulting the more detailed descriptions given in the succeeding pages.

The writer wishes to express his thanks to Prof. F. W. Brodrick for the use of the plots for the spraying experiment and to Mr. J. F. Higham for much careful assistance.

Diseases affecting leaves:

Whole plant affected, unthrifty,
- Leaves rolled, crisp ..... **Leaf roll**
- Leaves mottled, crinkled or curled ..... **Mosaic, etc.**

Leaves only affected:
- Roundish, brown spots on leaves ..... **Early blight**
- Margins and tips of leaves browned ..... **Tipburn**

Diseases affecting stems, and often tubers also:
- Lower stem with dry, brown scars; black masses on tubers... **Rhizoctonia**
- Lower stem rotted, black, slimy at first; tubers soft rotted... **Blackleg**
- Plants wilted, stems brown inside; brown ring in tubers..... **Wilt**

Diseases affecting tubers:

Roundish, brown, corky spots on tubers	**Scab**
Rot in storage, brown, dry	**Dry rot**
Rot in storage, soft, slimy	**Soft rot, see Blackleg**
Tubers soft or discolored within	**Frost injury**
Tubers with hollow area near centre	**Hollow heart**
Tubers brown netted or spotted within	**Net necrosis**
Tubers with black area near centre	**Black heart**
Tubers produce weak, spindly sprouts	**Spindling sprout**

If a potato plant or tuber shows symptoms that cannot be matched otherwise, see paragraphs on rare, lesser, or threatened diseases.

DISEASES AFFECTING LEAVES

LEAF ROLL and MOSAIC caused by Protozoa

Leaf roll and mosaic are perhaps the most threatening of potato diseases at present in Manitoba. These diseases bring about what is frequently called "degeneration" or "running out" in potatoes. It should be emphasized that not only the leaves, but also the whole plant are affected by leaf roll and mosaic, and the yield is reduced; the leaves, however, show the most conspicuous symptoms. Each of these diseases is transmitted from year to year by planting tubers from affected plants. Each may be spread in the field by plant lice (aphids) and perhaps by other insects. The soil is not affected, so that a healthy potato crop may be grown on a field which produced leaf roll or mosaic the previous year. These are not new diseases; but have existed in the potato crop for 150 years and probably longer, but until recently were recognized only as symptoms of the so-called "degeneration" of varieties. It is now generally admitted that potato varieties do not "run out" except through disease, particularly of the leaf roll or mosaic type. These diseases were probably introduced into Manitoba some years ago with seed potatoes and are now widespread in the province.

Leaf roll and mosaic are caused by small living organisms which occur in the sap of the plant and cannot be reached by sprays or seed treatments. The eradication and prevention of these diseases are problems which require careful, and wherever possible, concerted attention. The best thing to do if these diseases occur in one's stock of potatoes is to dispose of the entire lot and obtain **healthy** seed. In general, the best way to be sure of getting healthy seed is to obtain **certified** seed or at least to obtain seed that you can feel confident is healthy and vigorous and free from weak, leaf roll, or mosaic plants. It does not pay to try to select healthy potatoes, or to remove diseased plants, from a stock of potatoes badly affected with these diseases. It is, in reality, usually practically impossible to eradicate these diseases entirely from a lot of potatoes in which they have become prevalent. Furthermore, **do not grow vigorous, healthy lots of potatoes you have or may get, beside diseased or doubtful rows of potatoes, either of your own or of your neighbor's.** Plant lice will spread these diseases, and, in a year or two, your stock will again produce very poor seed potatoes and reduced yield, unless care is taken to keep **at least the plot which will produce your seed** separated from all affected or doubtful plants. Unless careful attention is paid to the growing of potatoes free from leaf roll and mosaic, not only will the growers' individual profits be reduced, but also Manitoba's reputation as a seed potato-producing area cannot be established. It is not only useless but also really dangerous to persist in planting some diseased "pet" variety that once gave good results; it will never "come back," and it is a serious source of infection for your own and your neighbors' potato fields.

Leaf Roll is characterized by an upward rolling of the leaves, particularly of the lower leaves, and a crisp, harsh, rigid character of the leaves affected. Diseased plants are smaller than normal plants, and appear more or less unthrifty and slightly "off color." Figure 1 (front cover) shows a serious attack of the disease, such as is frequently seen in Manitoba. In less severe infection, considerable attention may be required to detect the disease in the field. The tubers are smaller than normal, set close to the stem, and may show a netting within (see net necrosis).

Mosaic is here considered as a general term to include the several similar symptoms or diseases known as mosaic, mosaic-dwarf, curly dwarf, crinkle, leaf-drop, etc. The leaves of affected plants are either mottled (this symptom is often visible only early

Fig. 2—Mosaic and Healthy Plants.

in the season, or even not at all, in this climate), crinkled, curled, or dwarfed. The whole plant may appear dwarfed, weak, or unthrifty in severe cases (Fig. 2); as in the case of leaf roll, mild cases are often determined with difficulty. Figure 2 shows seriously-diseased and healthy plants of the same ages.

EARLY BLIGHT, caused by Alternaria solani

Early blight has not been found to be a very serious disease in Manitoba. In certain years, such as 1921 and 1922, when warm weather with some periods of dampness occurs, the leaves may show considerable spotting from this disease. The brown, dry, dead spots may occur on any portion of the leaves; these spots are usually roundish, and often marked with concentric rings. The stems and tubers are affected only indirectly. The fungus overwinters on the old potato plants in the field.

Ordinarily no particular attention need be paid to this disease, but note the discussion under Bordeaux mixture (page 16).

TIPBURN (Hopperburn and Sunscald)

Tipburn is also usually a lesser disease of Manitoba potatoes. The leaves turn brown and dry at the tips and edges. If leaf hoppers are responsible for the trouble, the browning will extend inward along the veins of the leaf; if heat causes the damage, the leaf tissue between the veins will be browned the more severely. Tipburning and early blight affect the crop only by reducing the leaf area which feeds the plant.

For control, see discussion of spraying (page 16).

DISEASES AFFECTING STEMS AND TUBERS

DRY STEM ROT and BLACK SCURF, caused by Rhizoctonia solani. "Rhizoctonia diseases"

These diseases are and will be among the most troublesome ones Manitoba potato-growers must face. The real damage to the plant comes from the attack of the fungus on the underground stems, stolons, and roots. The sprouts may be killed before the surface of the soil is reached. Such sprouts and the underground portions of affected plants show definite brown, dead areas on the surface. Strands of the fungus can be seen with a lens. Many of the "misses" in Manitoba potato fields are caused by the early attack of Rhizoctonia on the sprouts. When older plants are attacked, "big vines and little potatoes" may result from the girdling of the lower stem by the fungus. Tubers may be borne in the axils of the leaves, or numerous small, irregular tubers may be set close to the underground stem. On the tubers, black scurf, which looks like dirt, but which will not wash off, is produced. These black, dirt-like masses are made up of the "spawn" of the fungus, which thus is carried over winter on the tubers. Black scurf is superficial and causes only an injured appearance of the potatoes, but when such tubers are planted without treatment the disease is more likely to be serious on the sprouts and plants produced.

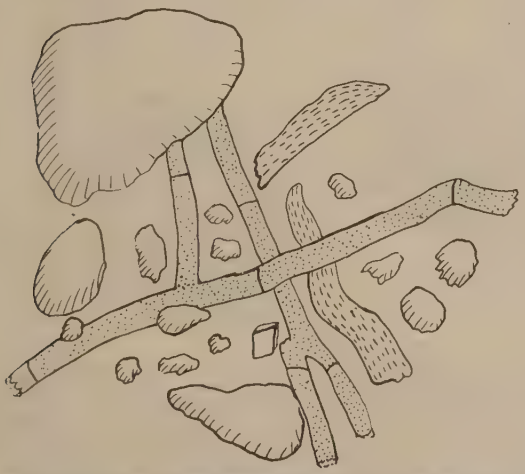

Fig. 3. The dotted strands represent threads of the fungus Rhizoctonia growing amongst soil particles and bits of decaying organic matter. This fungus can live naturally in the soil; but as a potato plant develops the fungus may attack the underground stems, or accumulate as black scurf on the tubers. Magnified 500 times.

The Rhizoctonia fungus lives naturally in Manitoba soils, and is especially abundant in heavy soils, such as occur in the Red River Valley. The fungus accumulates in the soil in greater abundance when crops of potatoes are grown frequently. Crop rotation is valuable in avoiding the excessive accumulation of Rhizoctonia and other fungi in the soils. Early digging may lessen the black scurf infection of tubers.

Fig. 4. Dry stem rot

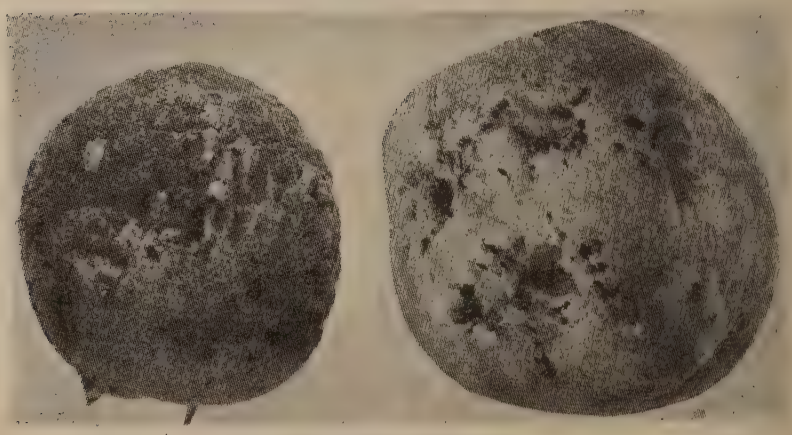

Fig. 5. Black scurf on tubers.
Figs. 4 and 5 show dry stem rot and black scurf, caused by the fungus Rhizoctonia.
(After Bisby and Tolaas).

Seed treatment may lessen the danger of dry stem rot on young sprouts; see discussion of this topic (page 12), and see also note on scab (page 9).

In spite of any known control methods which may be practised, it must be recognized that, in certain types of soil, some of the tubers grown will inevitably bear black scurf. This is not, however, a very serious matter. If a good rotation of crops is practised, accompanied if necessary by seed treatment, potato growing will not be precluded by Rhizoctonia.

BLACKLEG, caused by Bacillus atrosepticus

Blackleg is a serious potato disease in cool and moist regions over much of the world. In damp and cool seasons it is common in Manitoba. The potato stem begins to rot below ground and becomes inky-black, slimy and soft throughout. The disease may extend also above ground. Affected plants turn yellow, wilt and usually die. The lower stem may later dry out and appear brown. Often the plants are attacked soon after they come up; but older plants may also contract the disease, and the tubers present may then become rotted with a soft, slimy rot with a disagreeable odor. This tuber rot may dry up and cease; under damp storage conditions, however, this or a similar soft rot may spread in storage.

Blackleg evidently overwinters only in affected tubers, since it has not been found to live over in the soil. Seed, therefore, should be saved from potato fields which do not contain blackleg, or any diseased plants should be removed from plots which are to produce seed potatoes. Seed treatment is a valuable precautionary measure. Tubers showing soft rot should be removed, so far as is possible, from the crop before or during storage.

WILT, caused by Fusarium oxysporum

Wilt is fairly common in Manitoba in warm seasons. It appears usually rather late in the season, so that some yield of tubers is to be found under affected plants, but these tubers may be of inferior quality.

As shown in Figure 6, wilted plants show a drooping of the leaves. The leaves may be rolled, but do not remain rigid as in leaf roll. The plants become yellowish and usually die prematurely. Wilt can be determined in doubtful cases by cutting off the stem near the ground line; the sap-tube area inside will be found to be browned. The fungus may pass through the stolons into the tubers and there develop as a ring discoloration, as seen when a slice is cut from the stem end of the tuber.

Fig. 6— Fusarium wilt.

Wilt is not, in the opinion of the writer, to be greatly feared in Manitoba. It is more serious farther south. The fungus is probably present in most Manitoba soils; probably it was naturally present. The following are impor-

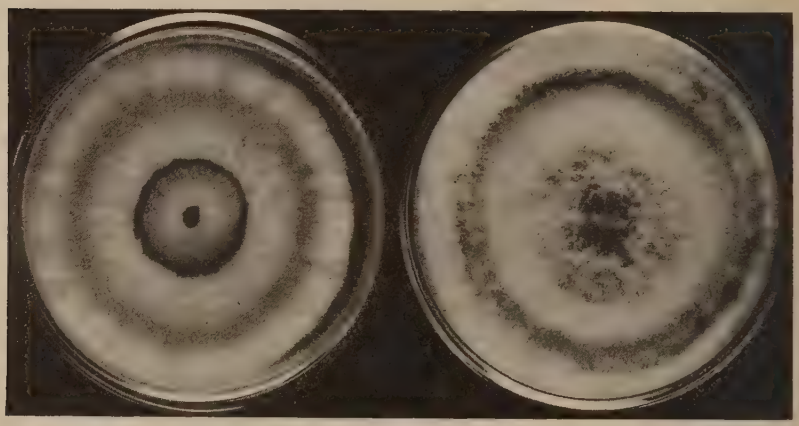

Fig. 7. Pure culture of a Fusarium on nutrient substance (agar-agar) in a glass dish. A bit of the fungus was placed in the centre of the dish, and the cottony growth filled the dish 4 inches in diameter in less than a week. A growth such as this may readily be obtained from the fungus within the browned area in a potato stem affected by wilt. The right picture shows a top view of the growth; the left shows a view of the bottom of the glass dish. This fungus may grow in the soil in a similar manner, though usually not so luxuriantly.

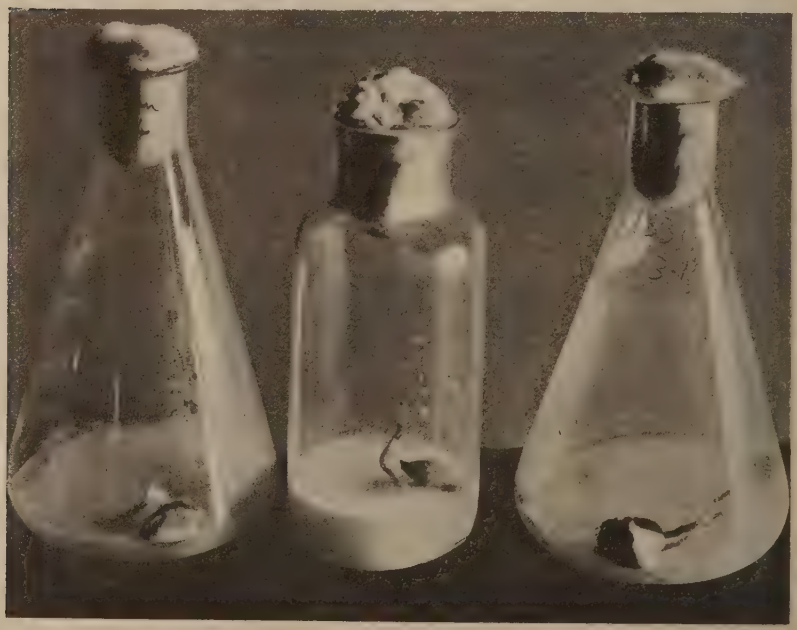

Fig. 8. One method of determining the manner in which fungi attack potatoes. The glass dishes contain sterilized agar-agar, upon which sterilized seed pieces of potato are planted. A pure culture of a fungus may then be introduced and its effect upon the plant and the seed piece followed.

Fig. 9. A bit of the thread-like growth illustrated in figure 7 highly magnified to show the strands of the fungus and its boat-shaped spores, or seed-like structures.

tant considerations: Rotate crops to avoid an accumulation of the fungus in the soils. The potato crop should be given care, for vigorous plants are able to resist attack. If a lot of seed shows considerable stem end browning, a slice of about half an inch may be cut from the stem end and discarded. A slight browning at the extreme stem end of the tuber is common and of no particular importance. If the tubers are found to be browned all through, in netted or patchy areas, read note under "Frost Injury" (page 10) and "Net Necrosis" (page 11). Dry rot is caused by a similar fungus to the one causing wilt.

Verticillium has not been found as a wilt-producing fungus in Manitoba, although most of the province has not been tested by isolations from wilted plants.

DISEASES AFFECTING THE TUBERS

SCAB, caused by Actinomyces scabies

Everyone knows potato scab. It is common in Manitoba, especially under warmer soil conditions. Scab does not ordinarily reduce the yield, but renders the potatoes unsightly and less valuable; the eyes may be injured, so that badly-scabbed tubers should not be used for seed even when treated.

The scab organism occurs naturally in the soil. Scab does not occur, however, except in soils with an alkaline reaction. Wood ashes, lime or fresh manure tend to make the soil more alkaline and hence to increase the amount of scab. Plowing under a green crop will aid in making the soil more acid and thus less liable to produce scabby potatoes.

Treatment of tubers is valuable; see this subject for results of experiments at the M.A.C. (page 12). It must be remembered that scab may occur on treated potatoes, since, like Rhizoctonia, the germ is present in the soil; but it is obvious that there is greater danger of scab and of Rhizoctonia injury if sets are planted bearing quantities of the organisms, which can then develop at precisely the spot where the plant and tubers are developing.

DRY ROT, caused by Fusarium discolor sulphureum and other Fusaria

Dry rot causes much loss in Manitoba. This loss is worse because it occurs in bins and cellars after all the expense and trouble of growing, harvesting and storing the crop have been incurred. Dry rot is seldom to be seen when the potatoes are dug, but develops during storage. The fungus enters the tubers usually through wounds in the skin of the potato. The rot grows through the tuber as a brown, compact, firm, more or less dry decay. The mold causing the rot can be seen in cavities in rotted areas, and, under moist conditions, also on the surface.

Dry rot, of course, spoils the value of the potato for eating purposes. When sets showing dry rot are planted, the rotting continues in the soil and may prevent the development of a sprout.

Dry rot can be lessened by the following means: Provide as clean, dry and well ventilated storage as is possible. The bins should be kept cool; 35 to 40 degrees Fahr. is

the best temperature for storing potatoes. Care should be exercised in handling potatoes; rough handling means bruises and rotted potatoes. The fungus causing rot may live over summer in bins and cellars, so that clean storage should be provided by scrubbing out and disinfecting the bins before the potatoes are put in (see "seed treatment," page 15, for method). When choosing potatoes for eating purposes, pick first the ones that show bruises or the beginning of rot; such potatoes are likely to rot during the winter and to contaminate other potatoes.

Soft rot (see blackleg, page 7) may occur during storage. The same general considerations apply for both rots.

FROST INJURY

In Manitoba it is inevitable that some damage from frost will occur to potato tubers. When a frozen potato thaws out, it becomes soft and watery; it rots and makes sound potatoes near it moist and more liable to rot. Frozen potatoes should not be placed or left in a bin with healthy potatoes. When a potato is only chilled, and not frozen, it may become blackish and blotched inside, and the sap tubes may turn brown. Its value may not be entirely destroyed for seed purposes, but it is in general better to plant potatoes that are not blackened inside.

Potatoes kept at a low temperature may become sweet; such potatoes are perfectly good for seed so long as they are not frozen or blackened, and the sweetness can be largely removed by keeping such potatoes to be eaten in a warm room for a week or

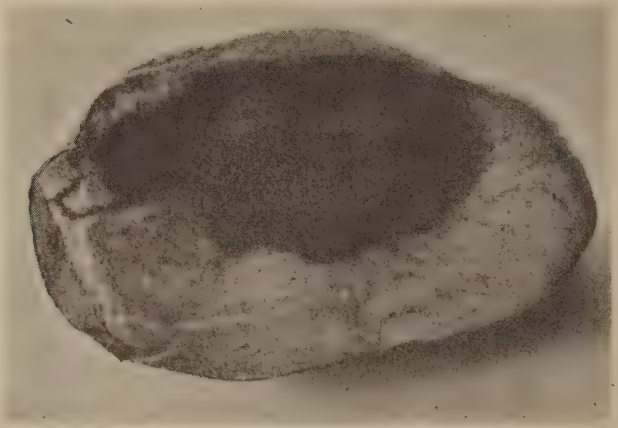

Fig. 10. Blackening and browning caused by chilling the potato.

so before they are cooked. It may be noted that a potato will not freeze at 32 degrees Fahr., so that a tub or pail of water in the coolest part of the bin may be used as an indicator. When ice starts to form on the water, heat the bin somewhat.

HOLLOW HEART

It is common to find potatoes, particularly large, roundish tubers, with a hollow area near the centre. This cavity is surrounded by a corky layer. Hollow heart is brought about by irregular or too rapid growth of the tubers. It is not at all serious. Potatoes with hollow heart make perfectly good seed. The trouble can be reduced by planting the potatoes closer together or by using varieties less subject to the condition.

NET NECROSIS

When tubers show netted brown or blackish areas inside, particularly along the bundle or saptube area, the condition is called net necrosis. A slight netting of the bundle area of the tuber is often found in Manitoba as a result, evidently, of dry weather and soil conditions. Recent work has shown that a similar but usually more severe netting may occur in tubers produced by leaf roll plants. Tests at the Agricultural College showed that tubers from healthy plants showing the slight, dry weather type of netting will produce healthy plants and a good yield. However, since it is difficult to determine what may have caused the discolorations within potato tubers, it is safest to plant tubers without such symptoms, unless one can be sure the plants which produced the tubers were healthy and vigorous.

A similar trouble, brought about by soil conditions, but in which irregular, brown blotches occur within the tuber, is termed "internal brown spot."

BLACK HEART

This trouble is not commonly found but occurs when the potatoes have been exposed (near a stove or furnace) to temperatures of about 100 to 113 degrees Fahr. for several hours. The same trouble may be caused by depriving the potatoes of air. The flesh turns pink or purplish, then black, in larger or smaller areas usually near the centre of the tuber. The remedy consists in avoiding overheating in storage or shipping, and in not piling the potatoes too deeply without ventilation.

SPINDLING SPROUT

Tubers from weak plants, or which have been improperly stored, may produce weak, spindly sprouts. Very small sets may also produce such sprouts. The trouble is not caused by a parasite. It can be avoided by the use of vigorous seed that has been stored properly. The vigor of a lot of potatoes can be determined in part by removing some of the tubers to a warm and damp place, so that the sprouts will start; the occurrence of spindling sprout can thus be determined.

LESSER, RARE, OR THREATENED DISEASES

The following are diseases which are found on potatoes in various parts of the world, but which are not present or not serious as yet in Manitoba.

Late Blight, caused by **Phytophthora infestans,** is one of the worst potato diseases known. It probably will not occur in most of Manitoba because of the dry atmospheric conditions. The leaves and tubers rot from this disease.

Arsenical Injury is sometimes found as a blackening on the leaves or stems of potatoes sprayed with too strong paris green or other arsenical. It is not serious and can be avoided by careful spraying or the addition of some lime to the poison applied.

Lightning occasionally strikes in a potato field and kills all plants in a circular area a rod or so in diameter.

Powdery Scab, caused by **Spongospora subterranea,** will probably not develop much, if any, in Manitoba, because of dry conditions. The scab spots are smaller than common scab, powdery, and surrounded by the torn skin of the tuber.

Black Wart, caused by **Synchytrium endobioticum,** is a very serious disease found in Europe, and has been introduced into Newfoundland and certain mining areas in the Eastern U.S. Most areas which produce this disease are fortunately under quarantine, so that there is no immediate danger evident. Affected potatoes swell into a cauliflower-like mass of warty growth.

Silver Scurf, caused by **Spondylocladium atrovirens,** is an unimportant trouble in which the surface of the potato becomes silvery in patches, and somewhat shrunken.

Skin Spot, caused by **Oospora pustulans,** is a minor trouble not yet found in Manitoba.

Sunburn is common on tubers which develop under exposure to the sun, at the surface of the soil, or which are stored where light strikes them. The surface and outer tissue become green. Such potatoes make good seed, but are absolutely unfit for eating.

Quack Grass Rootstalks sometimes grow through potatoes.

Witches' Broom is a rare condition in which the tops of the plant are made up of dozens of fine branches with small leaves. Use vigorous seed to avoid this.

"No Tops" refers to a peculiar condition sometimes found in which the sets produce small tubers directly instead of producing normal sprouts. May occur from weak seed or very dry soil conditions.

Weakness and **"Running Out"** are covered, for the most part, under leaf roll and mosaic. Under certain conditions, however, weak, sickly plants may develop, as noted in part previously, from tubers stored under poor conditions, particularly under warm conditions and **when the resulting sprouts have been removed one to three times,** or when the plants the preceding year grew under very unfavorable conditions. It should be emphasized that the first sprouts a potato tuber produces are its best; the second or tertiary sprouts may be very weak.

METHODS OF PREVENTION OR CONTROL OF POTATO DISEASES

Much of the loss from potato diseases may be prevented by good agricultural practices such as the use of the best seed, rotation of crops, and general care. The importance of these practices has already been noted in part and is further discussed briefly below in their relation to producing healthy potatoes. There are, however, two control measures which may be considered as applying particularly to the prevention of potato diseases. These are seed treatment and spraying.

SEED TREATMENT

Seed treatment is as yet scarcely used by Manitoba potato growers. The advantages of seed treatment have been demonstrated in many other regions, and tests were undertaken at the Agricultural College in 1920, 1921 and 1922, to determine the value of this method under Manitoba conditions. In 1920 treated seed produced tubers only 4.6 per cent. of which had scab, whereas 18.3 per cent. of the tubers from untreated seed were scabbed. There was practically no difference as regards black scurf on the progeny of treated and untreated seed tubers. The results during 1921 are given here in full since quite definite data were obtained. It must be recognized, of course, that further tests must be made before final conclusions can be drawn, and that different soil and seasonal conditions will inevitably affect the results that one may obtain. The figures and discussion are submitted as indicating some value for seed treatment, and it is suggested that potato growers can well give treatment a trial under their conditions; but it must be understood that treatment cannot be depended upon to give a crop free from scab or black scurf, since infection in both these diseases may come from the soil. Tables I. to IV. give the results.

TABLE I.—RESULTS OF TREATING POTATOES AT M.A.C. IN 1921

Row	Seed Used	Treatment Used	Time Treated	Date Dug	Number of Tubers			Total Number*	Weight Lbs.	Per cent. of Tubers	
					Clean	Scurfed	Scabby			Scurfed	Scabbed
1	Scurfed	None	.....	Aug. 20	181	29	179	387	130	7.5	46.3
2	Scurfed	None	.....	Aug. 26	61	180	175	333	115	54.0	52.6
3	Scurfed	None	.....	Oct. 13	11	358	183	383	116	93.5	47.8
4	Clean	None	.....	Aug. 30	91	155	114	319	117	48.6	35.9
5	Scurfed	Copper sulphate—1-150	2 hrs.	Aug. 31	124	147	2	273	104	53.8	0.7
6	Scurfed	Copper sulphate—1-150	1 hr.	Aug. 31	89	196	21	295	113	66.4	7.1
7	Scurfed	Copper sulphate—1-150	½ hr.	Sept. 1	69	231	10	303	110	76.2	3.3
8	Scurfed	Copper sulphate—1-100	½ hr.	Sept. 1	88	201	12	294	103	68.4	4.1
9	Scurfed	Formaldehyde—1-240	2 hrs.	Sept. 1	92	207	9	306	120	67.6	2.9
10	Clean	Corrosive sublimate—1-1,000	1½ hrs.	Sept. 2	99	233	3	335	122	69.5	0.9
11	Scurfed	1-1,000	1½ hrs.	Sept. 2	79	215	3	297	117	72.4	1.0
12	Clean	None	.....	Sept. 9	23	300	58	336	122	89.3	17.3
13	Scurfed	Copper sulphate—1-150	2 hrs.	Sept. 9	8	322	7	335	108	96.1	2.1
14	Scurfed	Copper sulphate—1-150	1 hr.	Sept. 9	27	329	12	361	115	91.1	3.3
15	Scurfed	Copper sulphate—1-150	½ hr.	Sept. 9	5	342	9	348	118	98.3	2.6
16	Scurfed	Copper sulphate—1-100	½ hr.	Sept. 8	12	313	28	320	100	97.8	8.7
17	Scurfed	Formaldehyde—1-240	2 hrs.	Sept. 8	21	353	37	376	124	93.9	9.8
18	Clean	Corrosive sublimate—1-1,000	1½ hrs.	Sept. 7	41	312	17	362	114	86.2	4.7
19	Scurfed	1-1,000	1½ hrs.	Sept. 6	51	286	16	343	108	83.4	4.6
20	Scurfed	None	.....	Sept. 6	3	307	150	320	101	95.9	46.9

*The total number of tubers is not the sum of the preceding numbers; because many tubers showed both black scurf and scab.

The figures 1-150, 1-240, etc., refer to the parts by weight respectively of poison and of water. "Scurfed" refers in all cases to black scurf. The "clean" tubers used were not entirely free from scab. The rows were uniform in length, number of hills, etc. Early Ohios were used, treated on May 7th, cut and planted on May 16th and 17th.

1—Yield as affected by treatment. The formaldehyde and corrosive sublimate treatments gave slightly better yields than were obtained from planting scurfed or scabby tubers without treatment (Table II.).

Table II. Yield after treatments. (From Table I.).

Kind of Tubers Planted	Treatment	Time Hours	Rows	Ave. Yield Lbs.
Scurfed	None	.....	*2, 3, 20	110.7
Clean	None	.....	4, 12	119.5
Scurfed	Formaldehyde	2	9, 17	122.0
Clean and scurfed	Corrosive sublimate	1½	10, 11, 18, 19	115.2
Scurfed	Copper sulphate—1-150	1 and ½	6, 7, 14, 15	114.0
Scurfed	Copper sulphate—1-150	2	5, 13	106.0
Scurfed	Copper sulphate—1-100	½	8, 16	101.5

*Row 1 is omitted from yield figures, because it was a border row and therefore yielded higher. All other rows are comparable. Row 20 was not a border row.

The potatoes used in the experiment were treated when the sprouts were just starting. It may be noted that other workers have also found, elsewhere, that, if tubers showing black scurf or scab, and not badly sprouted, are treated, the average yield will be better than obtained from planting similar untreated tubers. The use of copper sulphate at the strength of 1 part to 100 parts water was found to injure some of the sprouts, and at the strength of 1 to 150 the solution may cause slight injury when the tubers are treated for two hours. Weaker solutions are not altogether effective. The use of copper sulphate (blue vitriol) is not recommended.

2—Black Scurf on the Progeny of Treated Tubers. Black scurf appeared on the tubers in 1921 in spite of treatment. A marked variation is evident, however, depending on date of digging. (Table III.).

Table III. Date of digging and amount of black scurf on tubers. (From Table I.).

Date Dug	Per cent. of Black Scurf on Tubers
Aug. 20	7.5
Aug. 26	54.0
Aug. 30-31	56.3 (average)
Sept. 1-2	70.8 (average)
Sept. 6-7	88.5 (average)
Sept. 8-9	94.4 (average)
Oct. 13	93.5

It will thus be seen that, in 1921 on the plots used, little black scurf had developed by August 20 (even in this case on a plot planted with untreated black scurf seed), whereas by the end of August half the tubers showed some black scurf, and a week or ten days later the amount had reached a maximum of 90 to 95 per cent. This was not increased (it is obvious that it could not be much increased) when the tubers were left in the ground until October. The soil evidently contained considerable Rhizoctonia.

Under other seasonal and soil conditions these results might have been different: but it is evident that black scurf is likely to be less on potatoes dug moderately early, and that treatment cannot always be depended on to give a crop with less black scurf. This does not, however, condemn seed treatment; treatment lessens the danger of sprout injury from dry stem rot (and thus tends to increase yield); it is valuable against scab; in soils with less Rhizoctonia, or under other conditions, it would probably lessen the amount of black scurf on the tubers.

3—Scab was much Reduced after all Seed Treatments.

Table IV. Effect of treatment on scab.) From Table I.).

	Average per cent.
Scab on progeny of affected, untreated tubers (4 rows)	48.4
Scab on progeny of partly clean tubers (2 rows)	26.6
Scab on progeny of all treated tubers (14 rows)	4.0

It will be noted also from Table I. that one could not escape scab by early digging, for scab develops during the growth of the tubers, whereas black scurf develops later in the season. In certain soils, more scab than four per cent. might easily develop on the progeny of treated seed; but it is certain that our experimental evidence, and a vast body of data from other regions in North America and elsewhere, demonstrates that seed treatment is a valuable control measure for scab. Most farmers recognize the value of seed treatment for grains; it is likewise a good practice for potatoes, although it must be remembered that it is not a guarantee of a clean crop.

Tests were made in 1922 in an effort to determine whether late planting might serve the same purpose as early digging in lessening the amount of black scurf on tubers, but it was found that in order to reduce the amount of scurf on the crop, the potatoes must be planted too late to be practicable. In 1922 again, however, early digging resulted in lessened amount of black scurf on tubers.

METHOD OF TREATMENT

Either corrosive sublimate (poison) or formalin (formaldehyde) may be used. Corrosive sublimate (mercuric bichloride) is a somewhat better agent for killing black scurf on tubers than is formalin; but either is effective against scab. The sublimate has the disadvantage of being deadly poisonous to man and beast if taken internally (at the dilution used it will not injure the hands; they should not, however, be kept moistened with the solution for an extended length of time, and should be thoroughly washed after using the solution). The sublimate solution is also somewhat harder to make, since the crystals or powder must be dissolved, and it cannot be used in metal vessels, because it corrodes them. Formalin kills considerable black scurf, as well as the scab germs on the tubers, is easily and cheaply obtained, is less poisonous than corrosive sublimate, and can be readily made up and used in any vessel. Neither solution when diluted for treatment will lose strength from exposure to the air. Both are, however, weakened from the potatoes, dirt, etc., which are put in during treatment.

Corrosive sublimate solution is made by dissolving 4 ounces of the sublimate in 2 or 3 gallons of hot water in a wooden pail, then by adding enough water to make about 24 Imperial gallons. Be sure the sublimate is dissolved, or the treatment will not be effective. Smaller or larger quantities may be made in the same proportion. For 6 gallons, use 1 ounce of sublimate; a pound of sublimate will make about 100 gallons of solution. The potatoes should be soaked in the solution for 1 to 2 hours. About four lots of potatoes may be treated in the same solution; a good plan would be to soak the first lot 1¼ hours, remove the potatoes and soak the second and third lots about 1½ hours, and the fourth lot about 1¾ hours. Then discard the solution and make and use a new one. Be sure to use wooden or cement containers for this solution.

Formalin solution is made by mixing 1 pound of formalin (40 per cent. formaldehyde), such as is used for treating wheat, etc., with 24 Imperial gallons of water, or 2 ounces to 3 gallons of water for a few potatoes, etc. Soak the potatoes as mentioned under corrosive sublimate solution or make the time of soaking a little longer; for example, 1½, 1¾, 1¾ and 2 hours for the four successive lots; then discard the solution and make a new one. Formalin treatment should prove a simple matter, for many growers already use a similar treatment for grain. Barrels or tubs may conveniently be used for the solutions, unless large acreages are planted, when special vats or tanks will save time. If barrels are used, it is convenient to have them raised somewhat from the ground or floor and provided with plugs near the bottom, which can be removed to draw off the solution.

Treat seed potatoes before cutting. Spread them out to dry in a clean bin or other place after treatment. The potatoes may be treated at any time before planting. Tubers badly sprouted should either not be treated at all, or treated only about ½ hour.

The formalin or corrosive sublimate solutions will not injure unsprouted tubers, or short sprouts, ¼-inch long or less. Longer sprouts suffer from the extra handling, and may be somewhat injured also by the solution during a 1 or 2 hour treatment.

For disinfecting bins, cellars or other containers for potatoes, a mixture of 1 pint of formaldehyde to from 5 to 10 gallons of water is valuable and non-corrosive.

SPRAYING FOR DISEASES

Bordeaux —Over most of Manitoba, spraying for the Colorado potato beetle ("potato bug") must be practised. Since late blight does not occur, and other leaf diseases are not ordinarily serious, it might be questioned whether the use of Bordeaux mixture would be of value. However, in many parts of North America it has been found that increased yields may be expected from the application of Bordeaux even in the absence of late blight. Tests were accordingly made at the College at Winnipeg to determine whether it paid to spray or dust with Bordeaux. The results showed that the spraying paid in 1921. (See Table V.).

Table V. Results of spraying and dusting with Bordeaux at the M.A.C. in 1921.

Plot	Treatment	Row Number*	Yield Lbs.	Ave. Yield Per Acre Bus.
1	Sprayed	2 3	234 230	178.2
2	Unsprayed	6 7	164 169	127.9
3	Sprayed	10 11	220 224	170.5
4	Unsprayed	14 15	202 194	152.1
5	Sprayed	18 19	224 227	173.2
6	Unsprayed	22 23	179 191	142.1
7	Dusted	26 27	203 187	149.8
8	Undusted	30 31	164 158	123.6
9	Dusted	34 35	155 141	113.7
10	Undusted	38 39	130 123	97.2
11	Dusted	42 43	119 123	92.9
12	Undusted	46 47	112 120	89.1

*Rows 1, 4, 5, 8, 9, etc., not included in yield because they were border rows of each successive 4-row plot

The results presented in Table V. may be summarized as follows:

	Bushels per Acre
Average yield of the 3 sprayed lots	174.0
Average yield of the 3 adjacent checks	140.7
Average increase from spraying	33.3
Average yield of the 3 dusted plots	118.8
Average yield of the 4 adjacent checks	113.0
Average increase from dusting	5.8

This field used did not have the best of soil, and it will be noted that the part of the field dusted tended to become poorer toward one end. This does not affect the results, however, since the plots followed each other side by side, 4 rows being sprayed, the next 4 rows left unsprayed, and so on for the three spray plots, then similarly, 4 rows dusted and 4 rows undusted, etc., for the 3 dust plots. The Bovee (or Beauty of Hebron) variety was grown. All plots had received early applications of arsenicals to kill the Colorado beetle.

The spray used was a 5: 5: 40 Bordeaux mixture, made as described below, and applied with a horse sprayer. Each plot of 4 rows was sprayed twice at each application, the machine travelling in opposite directions. This covers the leaves better, and was considered advisable because the sprayer had but one nozzle per row. Spraying was thus done 3 times—on July 16, July 25, and August 4.

The dust used was Sander's copper-lime mixture, made of dehydrated copper sulphate and lime, ground fine, prepared "ready made" by a commercial firm, and applied with a hand duster on July 18, July 27 and August 8.

The yields in all cases were taken only from the two middle rows of each 4-row plot. This avoids confusion from spray or dust having been carried to the outer adjacent rows of the check plots. The figures obtained were quite consistent, and can be considered to show conclusively the value of Bordeaux spray under the conditions of the experiment. Whether or not similar results would be obtained under other conditions, in a different season and with different varieties of potatoes, etc., requires further experiment. In any case the results from spraying are definite enough to warrant a grower giving it a trial; each grower must, to a certain extent, determine the value of spraying for his own conditions.

The sprayed plots were noticeably better during the summer, and remained green about 2 weeks longer in the autumn than did the unsprayed plots. This was partly for the reason that flea beetles did not attack sprayed leaves, but were quite abundant on unsprayed plants; partly because early blight and tipburn were lessened, and partly for the not fully explainable reason that potatoes sprayed with Bordeaux have a lengthened period of growth.

The dusted plots did not remain green longer than the checks, and could not be differentiated by their appearance from the check rows throughout the summer. Dusting has been found valuable under the damper conditions of the Maritime Provinces, but may not prove so effective under our dry conditions. Final conclusions must not, however, be drawn from one season's work.

Preparation and Application of Bordeaux Mixture —A 5: 5: 40 formula is recommended. The first figure refers to the number of pounds of copper sulphate (blue vitriol), the second figure to the number of pounds of lime, and the third figure to the number of Imperial gallons of water. Crystals of copper sulphate should be used. These are of a blue color, and are poisonous if taken internally. The "slaked" or white powdered copper sulphate is somewhat stronger because it has lost some moisture. Unslaked or stone lime should be used if obtainable, although powdered or "prepared" lime can be used, but requires careful straining. Clean water from a well makes better Bordeaux than dirty water from a pond.

When stone lime is obtained, it should first of all be slaked by adding a little water carefully, then add enough water to make 1 gallon of mixture for each pound of lime. Thus, if 20 pounds unslaked lime is purchased, put it in a tub or other container and carefully add water until 20 gallons are added. Then to make up Bordeaux, several methods can be followed. To make smaller quantities, 40 gallons for example, place 20 gallons of water in a wooden tub or barrel, and hang 5 pounds of copper sulphate in a coarse cloth so that the sulphate is just below the surface of the water. It will dissolve in an hour or two when this is done. Then take 5 gallons of the lime mixture (stirred

well first) which will contain 5 pounds of lime and put this in another barrel and add 15 gallons more of water. Then keep the lime and water well stirred and pour both solutions into the sprayer through a fine strainer (use wooden pails for the copper sulphate, and avoid an iron strainer), so that the two solutions mix in pouring. Or a simpler and almost as satisfactory method would be to add 5 gallons of the original strong lime mixture through any fine strainer into the sprayer; then add about 10 gallons of water; then pour in the 20 gallons of copper sulphate solution; then add a final 5 gallons of water. The Bordeaux, after being mixed, should be used the same day it is made.

Where considerable quantities of spray are to be used, a convenient method is to dissolve the copper sulphate in a wooden barrel at the rate of 1 pound of sulphate to 1 gallon of water, or 40 pounds in 40 gallons of water, by hanging the sulphate in a sack near the top of the water. This solution and the lime mixture will keep indefinitely, but the barrels or tubs should be kept covered to avoid the evaporation of the water. Then to make a 40 gallon tank of Bordeaux, fill the spray tank about one-third full of water, add through a strainer 5 gallons of the stirred lime mixture (containing a pound of lime to the gallon of water); then fill the tank up to about two-thirds full with water; then add 5 gallons of the strong copper sulphate solution, and fill the tank with water.

Paris green, arsenate of lead, or other poison for insects can be added to the Bordeaux mixture if necessary. Add the usual amount of poison to the sprayer just as if the Bordeaux mixture were water.

Spraying with Bordeaux should begin when the plants are about a foot high. If the sprayer has only one nozzle per row, it is a good plan to go over the field twice, going the second time in the opposite direction from that which was followed on each 4 rows the first time. Apply 50 to 100 gallons per acre. The use of about three different applications at different times is suggested. If the vines become so large as to cover the ground, do not spray if it means too much trampling. Better results will follow the use of sprayers with 3 nozzles per row and high pressure. Any grower who is interested is advised to try Bordeaux on part of his field and to determine for himself whether the yield of potatoes is increased under his conditions. Bordeaux will lessen the amount of early blight and tipburn.

VALUE OF A SEED PLOT IN PREVENTING POTATO DISEASES

Having obtained a healthy, vigorous strain of a variety of potatoes, it should be kept up and improved by the use of seed plots. This plot is grown to provide seed for the next year's general crop. It should, therefore, be about one-tenth the size of the field to be planted to potatoes the succeeding year. The seed plot should be on the best part of the field and on soil which has not grown potatoes for some time. It should be isolated from other potatoes; though it may be placed at one side of the general field. The best selected seed should be used for the seed plot: it is an excellent plan to select by hand enough healthy, uniform, medium-sized tubers from the bin to plant the seed plot. The seed for the seed plot should be treated. The best care should be given this plot, and **about blossoming time go through it and remove** ("rouge out") **vines and tubers of all plants that are weak or diseased with leaf roll, mosaic, blackleg or wilt, and any mixtures of other varieties** In the autumn, before the vines are entirely dead, the best way to provide for the next year's seed plot is to "hill select" tubers from the best hills; that is, dig by hand the best appearing plants and save tubers from hills that produce a good yield of uniform tubers that are healthy and true to the type of the variety. Then the remainder of the seed plot should be dug and stored separately to be used as seed the following year. The seed plot method agrees with the best agricultural practice and can be followed easily and profitably. It has repeatedly been demonstrated that this method pays handsomely in increased yield and lessened disease.

SUN SPROUTING

Sun sprouting the seed potatoes is valuable for plots of potatoes that are planted by hand. The tubers are placed in a sunny or light place for two or three weeks before planting. Sturdy, green sprouts are produced, which develop rapidly when the sets are planted. Tubers producing weak sprouts should then be discarded. Sun sprouted potatoes cannot well be used when a potato planter is used, for the sprouts become broken off.

CUTTING SEED

In general it pays to cut the seed by hand, since diseased tubers can then be readily discarded. The cut "seed" should be kept in a clean place and spread in a thin layer so that it will dry quickly. Under damp conditions, such as prevail when the "seed" is sacked immediately after cutting or otherwise allowed to remain moist, rots develop on the cut surfaces and markedly reduce the stand obtained when the sets are planted.

CROP ROTATION

Crop rotation is valuable, as already mentioned, because it avoids the accumulation in the soil of various organisms which attack potatoes. The use of a rotation is also the best general agricultural practice.

HANDLING, STORING AND SHIPPING POTATOES

Much loss to a potato crop may occur after it has been produced. A certain amount of cutting and bruising is inevitable when potatoes are being dug and put into bins; but few growers are sufficiently careful to keep this injury down to the minimum. The damage may not be evident until towards spring, when many of the cut and bruised potatoes will commonly be found rotted. This rotting is worse when potatoes are put into cellars which have not been disinfected as previously mentioned. Other suggestions are given under "dry rot," page 9. When potatoes are to be loaded into a car for shipment, care should be taken to exclude all rotting tubers, and to see that freezing or overheating may not occur during transportation.

SUMMARY AND CONCLUSION

This bulletin aims to present descriptions of Manitoba potato diseases, and to give suggestions for their control. There are a number of potato diseases, but few are serious here. The following points need to be emphasized:

Be sure of the health and vigor of the seed planted. Leaf roll and mosaic are quite common in Manitoba; each grower should do his best to avoid using or growing for seed potatoes which contain these diseases.

Seed treatment is suggested as a simple and inexpensive method of lessening certain diseases.

Bordeaux mixture can be expected to add to the yield; it deserves trial by those who specialize in potatoes, or have time for it.

The use of a seed plot is a simple and highly important method of keeping up, or improving, the health and yield of the potatoes grown.

Various other good agricultural practices should be utilized; their advantages include the lessening of diseases.

The best method for the control of plant diseases is the production of varieties resistant or immune to the various diseases. There is, however, at present no potato variety on the market which can be considered resistant to the diseases enumerated in this bulletin as occurring in Manitoba. Growers will be notified when and if such varieties may be produced; in the meantime the standard varieties for Manitoba (the Early Ohio, Beauty of Hebron, Irish Cobbler and Green Mountain types) should be grown, and careful attention paid to their health and vigor.

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THE LITERATURE ON THE CLASSIFICATION OF THE HYSTERIALES

BY

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THE LITERATURE ON THE CLASSIFICATION OF THE HYSTERIALES.

By G. R. Bisby.

The group of the Ascomycetes known as the Hysteriales is at present commonly considered to include a large number of forms characterized by fruit-bodies (known usually as perithecia or apothecia) which open tardily by a longitudinal fissure. The accretion of forms into this group is reflected by Saccardo, who gives, in volumes II, IX, XI, XIV, XVI, XVII and XXII of the *Sylloge Fungorum*, seven hundred and three references to the Hysteriaceae and thirty-eight to the Hemihysteriaceae, included in a total of fifty-one genera. Eliminating duplicate, varietal, and revoked references, there remains a total of some six hundred and seventy species in forty-six genera in these two related groups in the *Sylloge*, and many species have of course been described too recently to be included.

The writer has gone over the scattered literature in an attempt to set forth the ideas of classification held by various workers on this group. The knowledge of these fungi has, of course, undergone much development during the past two centuries, but the Hysteriales are still comparatively poorly understood.

Few early botanists devoted much attention to the fungi, and even when fungi were noted, the conspicuous forms naturally received first attention. The hundreds of Hysteriales, Pyrenomycetes, Lichens, and other small, undescribed fungi which occurred in the woods and fields would either be unnoticed, or could be described only vaguely prior to the close of the 18th century. Certain Hysteriales and other fungi were included in

some of the early descriptions of lichens. Thus Ray (1, p. 71) may have observed one of the Hysteriales; he gave the following description in 1724: "48. Lichenoides crusta tenuissima, peregrinis velut litteris inscripta. Found by *Dr Doering* at *Westerham*, a little beyond the Schoolhouse on a Tree in the Lane, that leadeth to *Querry's* in *Kent*." There is nothing very distinctive about this description, which would probably more aptly apply to certain lichens, but the Latin diagnosis was quoted verbatim by Micheli, Dillenius, Linnaeus, Haller, and others, and after modification and elaboration came finally to be involved in the synonymy of *Hysterium pulicare*, and also in the synonymy of the lichen *Graphis scripta*. In other words, various writers following Ray considered that the material they examined agreed with the general description Ray had given, or with the descriptions subsequent writers had elaborated from Ray's description and an examination of other material, until finally a definite plant could be recognised.

Micheli (2, p. 102) described: "7. Lichen crustaceus, tartaricus, arboribus adnascens, niger, & veluti deustus, receptaculis florum transverse oblongis, & quasi reniformibus non intortis, brevibus. Tab. 54. fig. 2. Per ambulacrum Imperialis villae in Ilicum cavernulis late se diffundens." This is referred to by Lightfoot and others as noted below. Micheli quoted Ray in No. 9, and noted "receptaculis florum sub cute erumpentibus, nigricantibus, transverse oblongis, varie divarigatis, & compressis." His numbers 10 and 11 are noted by Dillenius and Linnaeus.

Dillenius (3, p. 125) quoted Ray, gave figures, and noted: "Pertenui constat crusta albicante, cui variae figurae lineae inaequales, nigrae,...sunt....Nec tubercula nec scutellae aliquae mihi visae sunt." He stated that this plant occurred on elms and oaks and considered Micheli's Nos. 9, 10 and 11 to be no more than varieties. Dillenius followed with "2. Lichenoides punctatum & rugosum nigrum. The black dotted wrinkled Lichenoides. Crusta est tenuissima candida, cui maculae transversim innascuntur nigrae, pro arborum aetate & magnitudine majores & minores, nunc ex punctis elevatis, velut tuberculis quibusdam parvis, nunc ex lineis oblongis, tanquam rugis, dense congestis conflatae. Quae rugae vel non, vel parum ramosae sunt, linea vel sulco in medio (per lentem) destitutae, secus ac in praecedenti specie. A qua porro differt, quod puncta & rugae densius congestae sint." This form he reported on beech and oaks where the bark was still smooth and equal.

Haller (4, p. 188) listed: "Lichen bivalvis de rimis efflorescens, ater, characteristicus," followed by Ray's words, but with reference only to "Dill. t. 18. f. 1."

Linnaeus (5, p. 343) in 1745 merely brought together these

previous descriptions in his "941. Lichen leprosus albicans, lineolis nigris characteriformibus," and quoted Ray, Dillenius' No. 1, and Micheli's No. 9, and included Micheli's Nos. 10 and 11 (following Dillenius) as varieties. In *Species plantarum* (VI, p. 1140) Linnaeus gave this the binomial *Lichen scriptus*, and the name *Lichen rugosus* to Dillenius' No. 2, with the description "Lichen leprosus albicans lineolis simplicibus punctisque nigris confertis."

References to these species of Linnaeus were given in a number of the Floras that were so commonly published by various workers who followed Linnaeus, but in most of these no new data that enlighten us regarding the Hysteriales are found.

Lightfoot (7, pp. 800, 801) in 1777 gave the following suggestive notes:—"[Lichen] scriptus. 1. Lichen leprosus albicans, lineolis nigris ramosis characteriformibus. Sp. pl. 1906. Micheli gen. t. 56 f. 3. Dillen. musc. t. 18. f. 1.

"On the smooth bark of trees, frequent, as on beech, oak, hornbeam, etc. This is readily distinguished by its black fructifications, resembling small oriental characters, which, under the microscope, appear to be longitudinally wrinkled.

"There are two very remarkable varieties of this lichen, which might perhaps be more properly considered as distinct species:

"Hebraicus α. The first has large black, smooth fructifications, standing in high relief, of no regular figure, but from their size and thickness have a rude likeness to Hebrew characters. *Fig. non inveno.*

"Pulicaris β. The other consists only of small black, oval tubercles each about the size of a flea, having a longitudinal furrow on the back. It grows generally in the crevices of the bark of old oaks. The figure of Micheli agrees with it. Gen. pl. t. 54. ordo 37. f. 2.

"Neither of these two last are in Dillenius's collection at Oxford." The specimens upon which Lightfoot based the above descriptions could not be found in the Lightfoot herbarium at Kew.

Wiggers (8, p. 86) transferred *Lichen scriptus*, *L. rugosus*, and others to his genus Verrucaria. Hoffman (9, p. 14) made Lightfoot's varieties into species. His figures (t. 3. fig. 2, e, f) are uncertain.

Bulliard (10, p. 187) figured and described rather indefinitely *Variolaria corrugata* on the bark of branches, and (p. 170) *Hypoxylon ostraccum*, both of which may have been Hysteriales.

Tode (11) in 1783 described *Acrospermum unguinosum* but the genus is usually stated to date from his 1790 work. In 1784 (12) he applied the name Hysterium to a fungus which he described

as "Fungus labiatus sessilis per labia distenta semen nudum superficiale ejaculans" with the species *H. quadrilabiatum.* He gave this the common name "Venusschwämme." No previously described similar species were mentioned. In 1790 (13, p. 8) *Acrospermum compressum* and two other new species were described and (p. 30) *Hysterium bilabiatum.* In 1791 (14, pp. v, vi, 3–5) he explained that *H. quadrilabiatum* proved to be, on further study, a weathered or altered Sphaeria, and he was uncertain about *H. bilabiatum,* so he re-described the genus as "Fungus oblongo-acuminatus, cavus, sessilis, linea transversali superne findendus, seminibus globoso-ecaudatis, discum obducentibus" and observed "medium hoc genus inter Pezizas & Lichenes." He referred to *Lichen scriptus* L. and to Wiggers and Hoffman. Three new species were described and figured. The genus Hysterium is usually stated to date from this revised description of it in 1791.

Bolton (15, p. 124, fig. cxxiv) described *Sphaeria sulcata,* giving Lightfoot's variety β as a synonym, and observed that "This is a small, black, oblong tubercle, the size of a small flea; it is prominent, and has a deep furrow along the back, from end to end, by which it seems as if cloven in two, but the ends are joined together at the base....The plant under the double magnifier appeared like a bivalve shell, when closed and seen in front...on twigs and branches of ash trees, when in decay." He gave good figures of the external appearance of the fungus.

Acharius (16, p. 20) in 1798 described *Lichen alneus* on the bark of old Betula and Alnus, and *L. elatinum,* both of which subsequent authors considered to be Hysteriales. Under *Lichen scriptus* he listed a total of twenty-nine author citations. These included, in addition to certain authors noted above, those who had compiled Floras and included this name. In 1810 (17, p. 265) Acharius changed the name to *Graphis scripta.* In 1814 (18) he described several species of Opegrapha, which were later transferred to species of Hysteriales.

Persoon (19, p. 83) listed *Hysterium nigrum* Tode, *Variolaria corrugata* Bull. and *Lycoperdon vulvatum* Latourette as synonyms of his *Hysterium quercinum,* and included, without synonyms, three other new species of Hysterium. In *Synopsis methodica fungorum* (20, p. xii, 98, etc.) he included Hysterium with Sphaeria, etc., in his order Sclerocarpi of the class Angiocarpi. Hysterium is described briefly as "perithecium oblongum, rima longitudinali dehiscens," and nineteen species are given. *Lichen scriptus* β *pulicaris* Lightf. and "Mich. Nov. gen. pl. t. 50, f. 2" are given as synonyms for *H. pulicare, Sphaeria sulcata* Bolt. for *H. Fraxini,* and the synonyms given above for *H. quercinum,* except that Latourette's species is omitted. (Latourette had

listed the name without description, in *Chloris Lugdunensis*, 1785). The genus Hysterium was considered in a broad sense by Persoon, and subsequent workers, especially upon examining the spores, placed certain of the species in other genera. Certain species of Xyloma as described by Persoon were also subsequently removed to the Hysteriales. Species of Acrospermum were placed by Persoon in the genus Clavaria. In *Mycologia Europaea* (21, p. 331) Persoon described Tryblidium.

Persoon brought together a number of similar fungi into the genus Hysterium, and made a considerable advance in systematizing the knowledge concerning certain forms which had previously been overlooked or placed in the lichens or in various genera of fungi. The workers up to, and even including, Persoon, had naturally not been able to make much headway with these fungi, since the internal, microscopic characters were still almost unknown. Rapid progress was soon made and it is unnecessary to attempt to follow the specific, or even later generic, changes that came to be made, but the systems of classification and development of knowledge may be followed in a general way.

Sowerby (22) illustrated and gave notes on several forms. Albertini and Schweinitz (23) followed Persoon.

De Candolle (24, p. 280) gave the name "Hypoxyla" to a group of genera including Sphaeria, Xyloma, Opegrapha, Verrucaria, Hysterium and Hypoderma. This last genus was described as new, for subepidermal Hysteria, and five species of Hysterium were transferred to it.

Muehlenberg (25, p. 101) listed *Glonium stellare* without description. The genus was later described by him in Fries (27). Nees (26, Ueberblick, pp. 72–86) included Antennaria, Hysterium, Sphaeria, Thelobolus and Nemaspora in his group Myelomyci (Kernschwämme).

Fries (27) in his *Systema Mycologicum* proposed the name Pyrenomycetes, with Xylomyci Willdenow, Sclerocarpi Persoon, Hypoxyla De Candolle, and Goniomyci and Myelomyci Nees, as synonyms. He included as orders Phacidiacei, Sphaeriacei, Cytisporei, and Xylomacei, but noted that the Phacidiacei were aberrant in that they were often cupulate, but had the general habit of Pyrenomycetes. Under the Phacidiacei he included Hysterium Tode (including Hypoderma DC.) with forty-eight good species, three more doubtful, four listed as aberrant, and some twenty other species were transferred, discarded, or noted; Glonium (under Muehlenberg's name) with *G. stellatum*: Actidium with two species; and the genera Rhytisma, Phacidium and Excipula. Lophium he included under Sphaeriacei. Acrospermum was placed in the Sclerotiacei of the Gasteromycetes.

In 1825 (28) Fries altered somewhat his classification of the Pyrenomycetes. He included under Sphaeriacei a sub-order Dichaenei with his genera Dichaena and Ostropa, and under Phacidiacei the sub-orders Patellarei including, among others, Tryblidium; Cenangei; Cliostomei including Glonium, Lophium and Actidium; and Phacidiei, including Hysterium. He noted for Hysterium that "Nominis Auctor est Tode, sed nulla illius species huc pertinet." In reality, as von Hoehnel (76) points out, the name should be cited as Hysterium Fries.

In these two works and in *Observationes Mycologicae* (29) and *Elenchus fungorum* (30) Fries gave various synonyms and author citations, including many of the authors previously mentioned in this summary. He did not pay much attention to spore characters in his descriptions of these fungi. Fries' later ideas are given below.

Brongniart (31, p. 93) included the "Tribes" Sphaeriacées (including Lophium) and Phacidiacées in the Hypoxylées.

Greville (32, Vol. II, pl. 167) in 1825 gave excellent plates of several Hysteria. He figured, for the first time, the asci and spores of certain forms. Greville placed Lophium with Hysterium in the Tribe Phacidiei of the order Phacidiacei. Acrospermum was included (Vol. VI) in the Gasteromycetes.

Chevallier (33) revived De Candolle's name Hypoderma, and transferred three species from that genus to his new genus Lophoderma. In 1826 (34, p. 432) Chevallier proposed the order Hysterineae to include Lophium, Hysterium, Lophodermium (as he spelled it here) and his new genus Schizoderma (? = Dichaena Fr.). This order he placed in his class Cheilomycei. Acrospermum he included in the Sclerotiaceae. Chevallier placed Leptostroma, Actinothyrium, Phacidium, Eustegia, Rhytisma, and Phoma in his order Rhytismaceae.

Schweinitz (35, 36) described for North America forty-three new species in Hysterium, Dichaena, Ostropa, Lophium, Glonium and Actidium, out of a total of sixty-seven species in these genera, which he considered to occur in his collections. Since he did not describe the asci and spores of these forms, much uncertainty still exists as to the nature of his species. Acrospermum was placed in his earlier work in Tremella. Schweinitz followed Fries' classification in his later work.

Duby (37, Vol. I, p. 718) followed Brongniart's classification. His later work is noted below.

Wallroth (38, p. xxix) included Xyloma, Phacidium, Tryblidium, Colpoma (a genus he described to include *Hysterium quercinum* Pers.), Lophium, Hysterium, Stictis, and Peziza in the Hymenomycetes of Fries.

Fries, in his *Epicrisis* (39, p. 1) proposed the name Discomycetes,

and in 1835 (40, p. 344) placed the Phacidiacei (including Glonium, Actidium, Hysterium, Phacidium, Rhytisma, and Leptostroma) in this class. The Dichaenei (including Actidium, Lophium, Ostropa and other genera) he left in the Pyrenomycetes, but noted "Transitum sistunt ad Discomycetes, sed discum verum non monstrant." (Actidium he included in both groups.) In 1849 (41, pp. 367, 400) he maintained the same general arrangement.

Mlle Libert (42) described Aylographum, and included it with Hysterium, Glonium, Actidium, etc., in the section Phacidiacei of the Xylomyci. Nees and Henry (43) and Rabenhorst (44) followed Fries.

Corda (45, 46) in 1842 gave the name Hysteriaceae to a family of his order Myelomycetes. The Hysteriaceae he subdivided into Stegiaceae (with Stegia), Hysteriaceae (including Ailographum, Hysterium, Sporomega Corda, and Lophium), Gloniaceae (with Hysterographium Corda and Glonium), Cliostomei (with Cliostomum and Actidium), and Phacidiei (including Phacidium, Heterosphaeria, and Rhytisma). Ostropa and Dichaena were placed in the Sphaeriacei. Spore characters were taken into consideration and several species were illustrated.

De Notaris (47) in 1844 considered spore characters further and made these the basis of classification of the Hysteriaceae. He divided the family into two sections: Phaeosporii, with Triblidium, Hysterium and Hysterographium, and Hyalosporii, with his Gloniopsis, and ten other genera. As the title indicates, these fungi were considered to be Pyrenomycetes.

Léveillé (48, p. 115) proposed Thécasporés as a division of Fungi, with subdivisions Ectothèques and Endothèques. The latter was divided into Tribes Rhegmostomés (including sections Hystériés and Cliostomés), Stégillés and Sphaeriacés.

Bonorden (49) followed Corda's classification.

Berkeley (50) proposed the name Ascomycetes for Léveillé's Endothèques. He (51, p. 379), however, followed Fries and other earlier workers in including Hysterium and other genera in the Phacidiacei.

Duby (52) in 1862 published his memoir on the Hysteriales. He considered that these fungi should be placed with the Pyrenomycetes for the following reasons: (1) the perithecia are horny or cartilaginous, (2) the perithecia are elliptical or linear, (3) they show a special method of dehiscence. He considered that the Hysteriales showed affinities with the Discomycetes (Pézizées) through Triblidium. Duby reviewed his previously stated ideas of their relations to, and differences from, the Lichens. He points out that Coemans had noted that the hymenium of the Hysteriales gives no reaction with iodine.

In discussing the value of diagnostic characters in the Hysteriales, Duby considered that de Candolle's separation on the basis of superficial or imbedded, and de Notaris' use of the colour of spores, were not of great value. Duby divided the Hysterineae into two sections, Lophiées and Hystériées, and made further subdivisions on the basis of dehiscence of asci. Under Lophiées he included Lophium as having dehiscent asci, and his new genera Ostreichnion and Mytilinidion as having indehiscent asci. In the section Hystériées he included Triblidium, Hysterium, Glonium, Aylographum, Hypoderma, Angelina, and Actidium with indehiscent asci, and Lophodermium, Sporomega, Coccomyces, Colpoma and Ostropa under dehiscent asci. Duby made a new genus Aporia, which he considered "anomalum et ambiguum." He gave generic and specific descriptions of the various forms, and illustrated twenty-five species. His division of genera on the basis of dehiscence of asci has not been followed.

The Tulasne brothers (53, Vol. I, p. 224; II, p. 258; III, p. 111) gave notes on several forms and illustrated one. In their classification they included the genera under Phacidiei. L. R. Tulasne (54) also recorded observations on the "spermagonia" of certain Hysteria.

Since 1865 there have appeared many works containing classifications, or revision of classification, of Fungi. Chevallier (33) had long since suggested a grouping which separated the Hysteriales from the Phacidiales, but Fries and many others had included the Hysteriales as a subdivision of the Phacidiales. Corda's suggestion of reversing the terminology and including Phacidiei under Hysteriaceae had not been followed. De Notaris (47) and Duby (52) had considered the Hysteriales as a distinct group, as did de Bary (55, pp. 190 etc.). Fuckel (56, p. 248) and Cooke (57, p. 750) followed Fries and included the Hysteriales with the Phacidiales in the Discomycetes. In a later paper Cooke (58) followed Duby.

Saccardo at first (59) followed in general the classification of Fries for these fungi, but later (60) carried de Notaris' (47) basis of classification on spore characters further and divided the Hysteriales into the Sections Hyalosporae, Didymosporae, Phragmosporae, Scolecosporae and Dictyosporae, placing them in the Pyrenomycetes. Spegazzini (61) elaborated further this idea in his "nova systematis carpologici dispositio," and classified the Hysteriales into Aplosporae, Didymosporae, Phragmosporae and Dictyosporae, each group being divided again into Hyalosporae and Phaeosporae. Thus, for example, the Aplosporae-Hyalosporae included the genera Aporia and Hypoderma. The Hysteriales he placed in the Angiothalamae (Pyrenomycetes). In 1883 (62) Spegazzini proposed the Hemihysteriaceae

with Morenoëlla, Schneepia and Hysterostomella, and he has added also other genera and species to the Hysteriales from his South American collections. In the *Sylloge* (Vol. II, p. 721) Saccardo modified his and Spegazzini's classification, and made nine sections, using descriptive words with Hyalo- and Phaeo- as prefixes.

Gillet (63) included the Phacidiales but not the Hysteriales in his work on the Discomycetes. Ellis and Everhart (64) included the Hysteriales in their work on North American Pyrenomycetes, although they remark that they had not at first intended to do so.

In Engler and Prantl, *Pflanzenfamilien*, Schroeter (65, p. 2) included the Hysteriineae, but not the Phacidiineae, in the Pyrenoasceae, but further on (p. 142) he included both these orders in the Discomycetes. Lindau (pp. 265–278) described the group, dividing it into five families. He noted that "Die Hysteriineae bilden eine Mittelgruppe" connected with the Phacidiaceae on one side and Lophiostomataceae on the other, being also similar to the Graphideae.

Rehm (66) went over Duby's collection and revised various forms. In Rabenhorst's *Kryptogamen-Flora, Die Pilze*, Rehm (67) discussed relationships, placing the order Hysteriaceae as a separate group between the Discomycetes and Pyrenomycetes. He classified the genera into three families, Hysterineae, Hypodermieae, and Dichaenaceae, with an "Anhang," Pseudohysterineae Rehm, to include Acrospermum. Several genera previously included in the Hysteriales were removed to the Pezizales. Rehm at various times added to the knowledge of the group (68, 69).

Boudier (70) did not include the Hysteriales in his work on the Discomycetes but Schroeter (71) and Seaver (72) so classified them.

Clements (73) in 1909 used the term "hysterothecium" for the fruit body of the Hysteriales and Graphidaceae.

During the past few years fundamental changes in the arrangement of the Pyrenomycetes and Hysteriales have been proposed. Theissen and Sydow (74) included several genera, which had been included in Hemihysteriaceae or Hysteriaceae, in their work on the Dothideales, and von Hoehnel (75) in 1918 removed several genera to the Phacidiales. In various of his *Mycologische Fragmente* von Hoehnel has given critical notes on genera of the Hysteriales. These notes of his and the views of other workers were summarized, and the results of further study were given, in his discussion "Ueber die Hysteriaceae" (76). Von Hoehnel pointed out that the group had come to be very unnatural. He considered the Hysteriaceae to be

Lophiostomaceae with more or less drawn-out perithecia (hysterothecia) and classified them with the Pyrenomycetes. He believed that these two families form a natural group, for which he proposed the name Hysterostomaceae.

Of the fifty-seven or more genera which had fallen into the Hysteriales, von Hoehnel decided that only ten of them really belong there. He gave a key for these genera, and separated out a new genus (or at least sub-genus) Psiloglonium, for species of Glonium without subiculum.

The disposition von Hoehnel would make of the genera to be removed from the Hysteriales may be indicated as follows:

To the Phacidiales (see also (75)): Schizothyrium, Hypoderma, Hypodermella, Hypodermopsis, Lophodermellina, Nymanomyces, Lophodermium, Lophodermella, Aldona, Colpoma, Hysteriopsis, Sporomega and Synglonium.

To the Ostropaceae (in the Discomycetes); Ostropa and Robergea; he would include these genera in a group with Stictis, Vibrissea, Schizoxylon, etc.

To the Triblidiaceae (formerly placed in the Phacidiales); Pseudographis, Rhytidhysterium, Tryblidiella, Tryblidium, and Delphinella (= Pleodothis and Pleoglonis).

To the Dothideales (see also (74)): Cycloschizon, Dielsiella, Hysterostomella, Mendogia, Parmulariella, Parmularia.

To the Lembosiaceae: Actidium, Aylographum (= Lembosiopsis), Hadotia, Morenoëlla, Lembosia, Lembosiella.

To the Sphaeriaceae: Delpinoëlla, Erikssonia, Graphyllium (= Clathyospora), Merillopeltis, and Schizacrospermum.

To the Patellariaceae: Baggea and Hysteropatella.

To the Cenangiaceae: Angelina.

To the Sordariaceae: Acrospermum.

To the Lichens: Phragmographium.

To be discarded: Aporia.

Table I includes the genera left by von Hoehnel in the Hysteriales, and gives the geographical distribution of the species so far as listed in the various volumes of Saccardo's *Sylloge*. In this table "Asia" includes the adjacent islands. It may be seen that there are a total of one hundred and thirty-two species listed as occurring in Europe, and one hundred and eleven in North America. Saccardo had not, of course, included data from various lists of fungi for different regions; there are for example many more than twelve species common to both Europe and North America. It must also be remembered that several species included by Saccardo have been or will be shown to be only synonyms.

The recent tendency to remove a number of genera from the Hysteriales merely indicates that the order had long remained

without comprehensive and comparative study. It still remains to be seen whether such radical re-adjustment as von Hoehnel proposed best fits a logical arrangement of the Ascomycetes; the intermediate position of the Hysteriales makes their study of high importance.

The scattered references to the parasitism of members of the Hysteriales have not been included in this paper, but it should

Table I. *Distribution of species according to Saccardo.*

	N.A. only	Eur. only	N.A. & Eur.	S.A. only	Asia only	Austral. & N.Z.	Africa only	Miscellaneous	Total
Dichaena	4	1	2	—	—	—	—	—	7
Farlowiella	—	1	1	—	—	—	—	—	2
Gloniella	5	21	—	12	6	2	—	1 doubtful	47
Hysterium	37	24	2	11	8	—	1	1 Eur., Asia and N.A. 1 Eur., S.A. and N.A.	85
Gloniopsis	7	19	1	3	1	2	—	2 doubtful	35
Hysterographium	18	11	5	10	3	—	4	1 N.A., Eur. and Austral. 1 N.A., Eur., Afr. 1 N.A. and Asia	54
Glonium	14	18	—	10	—	2	—	1 N.A. and S.A. 3 Eur. and S.A.	48
Bullardiella	—	1	—	—	—	—	—	—	1
Mytilidion	3	12	—	1	—	—	—	—	16
Ostreion	1	—	—	—	—	—	—	—	1
Lophium	4	5	1	1	—	—	—	—	11
Total	93	113	12	48	18	6	5	12	307

be noted that Tubeuf (77) succeeded in growing *Lophodermium pinastri* in pure culture. Brefeld had previously failed to culture a species of Lophodermium. Tubeuf did not succeed in producing infection on pines by artificial inoculations from his culture.

Summary.

The members of the Hysteriales were at first confused with lichens, certain of which they resemble. Early workers inevitably drew up vague descriptions of these fungi. The name of the group is based on the genus Hysterium, which was first used by Tode. The type species is *H. pulicare*, the name of which can be traced back to Lightfoot. Persoon succeeded in bringing a number of similar forms together, largely by an inclusive interpretation of the genus Hysterium. Chevallier first used the name "Hysterineae" for an order, and he also separated into another order certain genera now included in the Phacidiales. This work has been generally overlooked in considering the beginning of a separate grouping of these fungi. Corda used the family name Hysteriaceae to include also the Phacidiales; most

other workers, down to the middle of the 19th century, including Fries, placed the genera now classified in the Hysteriales with the Phacidiales. The genera came finally to be distinguished principally on the basis of the colour, shape, and septation of spores.

There has always been confusion in the use of names to distinguish orders, sub-orders, families, etc.; indeed, the same name is sometimes used by a writer in two senses: see Corda's arrangement. Several mycologists (Saccardo, Spegazzini, von Hoehnel (76), and others) include all the genera in one family; if von Hoehnel's contentions that Dichaena should be placed in a separate family, and that the Hypodermataceae, Ostropaceae, and Acrospermaceae all belong elsewhere, should be followed, only the family Hysteriaceae is left of those now usually (64, 67, 71) included in the order.

The Hysteriales have been placed in the Pyrenomycetes and Discomycetes about equally commonly, which indicates clearly that they form a transitional group; Rehm (67) compromised by placing them intermediately. Certain genera have likewise undergone a great amount of shuffling; the most conspicuous example being Acrospermum (which Tode (13, p. 8) described as "Fungus simplicissimus"!), which has been placed, as noted herein, in Clavaria, Sclerotiaceae, Tremella, Phacidiales, Hysteriales, Pseudohysterineae, Sordariaceae and recently by Riddle ((78) agreeing with Ellis and Everhart) in the Hypocreales. The most recent tendency is to reduce considerably the number of genera included in the Hysteriales.

Pycnidial stages, attributed to the Hysteriales, have been noted by certain workers (54, 64); these are usually hysterioid in nature, and include Leptostroma and Psilospora.

Many workers not mentioned herein have described species, extended the knowledge of the distribution, or added other data regarding the Hysteriales. It is obvious, however, that the group is still in need of comparative and synthetic study.

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EXTENSION BULLETIN No. 71

Cereal Diseases in Manitoba

[This bulletin is a revision of Extension Bulletin No. 44, and is written for the reference of students in schools, and of Manitoba farmers who wish to increase the quality or quantity of crop production through the avoidance of certain plant diseases.]

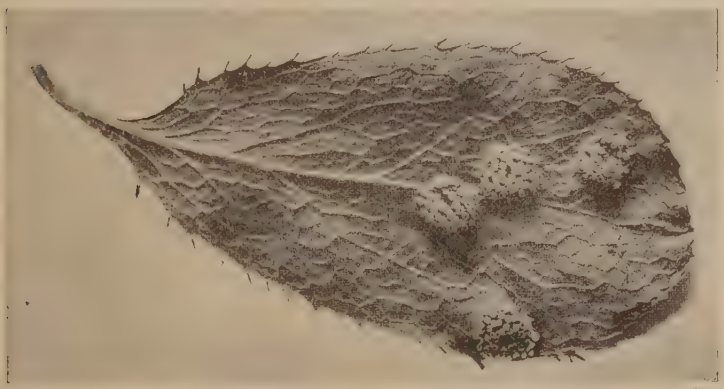

Photo by Howitt

The Cluster Cup Stage of Stem Rust on a Barberry Leaf

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Summary of Methods for the Lessening of Cereal Diseases

For BUNT of wheat, OAT SMUTS and BARLEY SMUTS, use one pound of standard strength formalin to 40 gallons of water. Clean the grain in the fanning mill before treating. Clean the floors, bins, sacks, wagon boxes, coverings, or anything with which grain may come in contact after it has been treated, by washing or soaking with the formalin solution. A smut machine may be used, but is not necessary. An easy method is that of dipping the cleaned grain in sacks in and out of the formalin solution until the grain in the centre of the sack is wet, then set aside in the sacks for 2 to 10 hours, and plant. Or spread the grain into a layer about 4 inches deep, sprinkle the formalin solution over it, shovel it over, sprinkle again, continuing until all the seed is moistened; then shovel in a pile and cover with heavy cloth for from 2 to 10 hours. It is better to sow the grain soon after treatment, setting the drill to sow one-fifth to one-fourth more per acre than when dry grain is used. Do not allow wet grain to freeze or heat. If the grain cannot be sown by the day after the treatment, spread it out to dry. Formalin is a good treatment for smuts and other diseases carried on the seed. Formalin may injure Liberty (hulless) oats, however. It is not necessary to treat rye or corn seed in Manitoba.

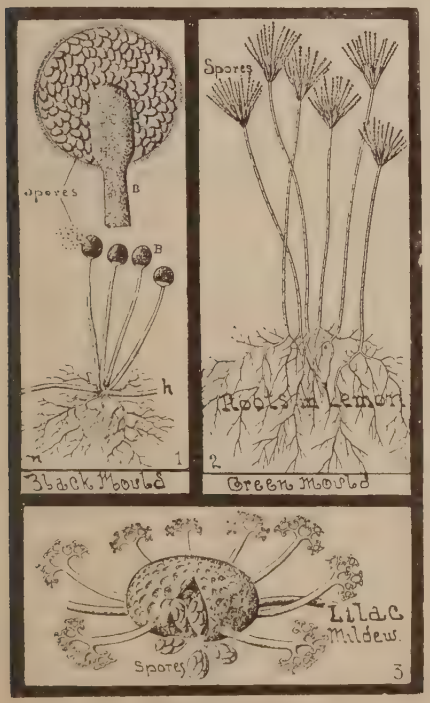
If LOOSE SMUT OF WHEAT occurs in the crop grown, try to get good seed free from this disease, and use a seed plot. It may be prevented by the hot water treatment, but this requires care.

RUSTS can be lessened by sowing early and using farm practices which make for early maturity or less rank growth of straw. White Russian oats are resistant to stem rust. Resistant varieties will probably eventually solve the rust problem, and complete barberry eradication over the spring wheat area will lessen the danger.

Certain other cereal diseases may be lessened by measures outlined in this bulletin, and other treatments are being tried experimentally. Good seed, good farming, crop rotations, seed treatment, and a careful consideration of the part that cereal diseases play or may play in crop production, will serve to reduce losses greatly.

Cereal Diseases in Manitoba

Most of the diseases of cereals, such as rusts and smuts, are caused by fungi. Fungi are plants without stems and leaves, and without the leaf-green (chlorophyll) which enables other plants to produce food in the light. Fungi must, therefore, live upon food already produced. Many fungi live upon (or within) and at the expense of living plants: these are called parasitic fungi, and they cause heavy losses of crops each year. Many other fungi obtain their food from dead organic matter; such fungi are termed saprophytic fungi, and are represented by most of the common mushrooms and puffballs that are so commonly seen in woods and fields in the summer, and by the moulds upon food exposed to the air in a damp place. Some fungi, such as the rusts, are able to develop only upon a living plant; others, such as those causing seedling blights, may also live on dead organic matter; still others, such as many of the mushroom fungi, cannot develop upon living plants. The saprophytic fungi may cause some damage from their growth upon food or lumber, for example; but their useful qualities far outweigh their injurious ones. They rot the dead leaves and fallen twigs and trunks of the trees in a forest, and thus form leaf mould, which can again be used as food by the trees; in fields they gradually decompose the stubble and weeds which are plowed under. It is evident that farming could not go on for long if the mass of plants and plant parts that is plowed under each year did not rot, and thus release plant food that previous plants had taken from the soil, and help to keep the soil in good tilth.



Figures 1, 2 and 3

All green plants require light in order to grow; but the fungi are not dependent upon light, and may be found in dark cellars or within the soil.

Instead of stems and leaves, fungi produce a thread-like growth called mycelium. This cottony growth can be seen in various moulds. In mushrooms the mycelium is often called "spawn." The mushroom itself is made up of large numbers of mycelial threads growing side by side. In many parasitic fungi the mycelium is within the stem, leaves, or other part of the plant, and cannot be seen without a microscope. Fungi produce, instead of seeds, very small bodies called spores. These are so small and light that they may be carried suspended for considerable periods in the air. Figure 1 shows a common mould much magnified; at the bottom is seen a little of the mycelium with finer root-like branches, and above, cases bearing spores. At the top is a single spore-case greatly magnified to illustrate the spores which are produced in large numbers within it.

Figure 2 illustrates the microscopic appearance of the green mould which grows on lemons and other fruits, food-materials, etc. At the bottom is shown the root-like growth of the mycelium within the lemon or other organic matter; at the top the spores are produced in rows upon the ends of finger-like processes. Figure 3 illustrates, enlarged, the tiny black dots which appear in the mildews. Each "dot" bears projections with branched ends, and contains little sacs containing spores. These spores live over winter within the cases, and some of them blow, or are carried by insects, to the proper plant in the spring, where the spores germinate and start the mildew again.

The drawing of Ergot (Figure 4) gives an idea of the complex life of certain fungi. The black ergot bodies (A, B) fall from grass or rye plants to the ground, where they live over winter; in the spring they germinate by producing several reddish "heads" (C); each of these bears many pits (D) each of which is filled with sacs containing spores (P). These spores escape through openings and some of them are blown upon grass or rye blossoms, where they attack the young seeds and produce many sticky spores which are carried to other plants by insects; then the ergot bodies (A) are again produced in place of seeds.

It may give an idea of the size of spores produced by fungi to note that a single kernel of wheat affected with bunt may contain from 8 to 12 million spores.

Fig. 4—Life History of Ergot.

Many people believe that weather produces disease in plants; for instance, that damp, warm weather produces wheat rust. This is true only in the sense that the spores of the rust fungus can germinate and cause infection only in the presence of moisture, and that the fungus develops more rapidly when the weather is warm. Weather conditions, such as frost or long drought, may injure plants, but most plant diseases, like animal or human diseases, are caused by living organisms; and cannot occur unless the "germ" is present.

Cereal diseases in Western Canada are now receiving considerable attention by both Dominion and Provincial Government workers. The Dominion Government headquarters for the study of cereal diseases is at Saskatoon under the charge of Mr. W. P. Fraser. The Dominion Government has recently appointed Mr. D. L. Bailey as plant pathologist, stationed at the Manitoba Agricultural College, and the Biology Department of the College works in co-operation with him on the study of cereal diseases.

PART I.

Rusts

GENERAL DISCUSSION

Rusts of cereals are by far the worst plant diseases in Manitoba. Rusts are exceedingly complex in their life-histories, and exhibit remarkable degrees of specialization in their attack upon cereals. Rusts have been known since biblical times, and the stem rust of grains occurs in every country in the world. Much of the knowledge of rusts has, nevertheless, been obtained only during the past few years.

As will be noted later, under the discussion of the diseases of wheat, oats, barley, and rye, each cereal may have two rusts in Manitoba, stem rust and a leaf rust. It is the stem rust (sometimes called black stem rust, *Puccinia graminis*) which causes the greatest rust damage in Western Canada. Stem rust may also attack the leaves, but leaf rusts do not attack the stems.

KINDS OF SPORES PRODUCED BY STEM RUSTS

It should be noted first of all that four important different kinds of spores may be produced in the life-history of stem rusts, and that one of these kinds is produced only upon the leaves of the barberry bush. "Red rust" and "black rust" are not different kinds of rusts, but only two stages in the life of the same fungus. The popular notion that black rust causes much more damage than red rust is erroneous; the black rust occurs after the cereal is weakened from the attack of the red rust; black rust **reflects** the damage, but the red rust **causes** most of it.

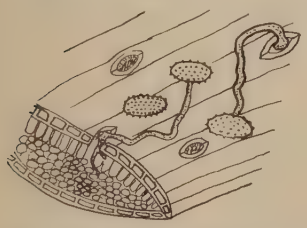


Fig. 5—Diagram to illustrate the germination of red spores on a cereal leaf, and the entrance of the germ tubes through the breathing pores of the leaf.

The four kinds of spores are as follows:

(1) The red rust spores, which break through the stems and leaves of the grain plants in the familiar spots with the torn epidermis of the stem or leaf surrounding them. These spores appear brick red in mass, and are often produced so abundantly as to rise in a cloud around the binder. The red rust is the only "repeating stage" of the rust; the red spores are easily dislodged from the plants, and are carried by the wind to other plants in the same or adjacent fields, or sometimes may be carried considerable distances in the air. Red spores may live for a month or more during the summer. When a living red spore falls upon the proper grain or grass plant, and moisture and warmth are present, the spore germinates as shown in Figure 5 and produces a sprout or germ tube which may enter the plant through the minute breathing pores that occur in large numbers over the surface of plants. The mycelium continues to grow within the leaf or stem of the plant, and in about a week in summer has developed sufficiently to produce another crop of spores which break through to the surface. Late in the season this mycelium may produce black spores instead of red spores. Black rust follows red rust, and is formed upon the same mycelium, but red spores never change over into black spores.

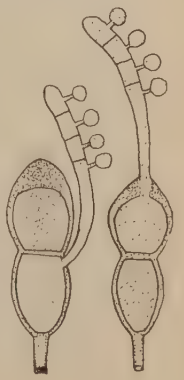


Fig. 6—The black spores of stem rust have two parts (cells), either or both of which may germinate in the spring and produce four small spores, which can infect only the barberry.

(2) The black spores make up what is known as "black rust." In stem rust these

spores also break through the stems and leaves of cereals and grasses to form the familiar black spots. The black spores, when viewed under the microscope, are seen to be made up of two parts, or cells, and are firmly attached to the host-plant by means of stalks; they do not blow from the plants. Black spores live over winter here; they do not germinate until the following spring; but they sometimes may germinate early in the spring; some black spores brought in February 23, 1923, germinated in the laboratory. Black spores will not attack cereals or grasses. Upon germination these spores produce a short bit of mycelium with four small spores upon it (Figure 6).

(3) These small spores produced from the black spores are carried about by air currents. Most of them fall on the ground, or on plants which they cannot attack, and in a short time they die; these spores will not even develop on cereals or grasses, but only upon one plant that may occur in Manitoba; that is, the common barberry. These spores which fall upon the developing barberry leaves germinate and grow directly through the surface of the leaf, and produce mycelium within; finally the mycelium aggregates together and produces masses of spores which break through the lower surface of the leaf to form "cluster-cups" in little groups. These are illustrated in Figure 7 and front cover.

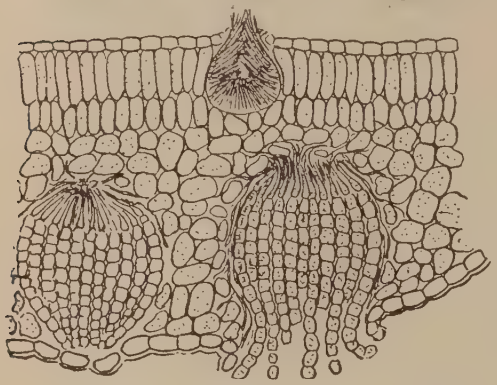


Fig. 7—Section of Barberry Leaf, showing the cluster-cup stage of Black Stem Rust of Wheat.

(4) The cluster-cup spores are roundish or oblong spores, about a thousand being produced in each cup. They fall or are blown from the leaf, but they will not again attack the barberry; but those spores which chance to fall upon the proper cereal or grass will develop and produce a crop of red spores. These start the story over again.

WHERE DOES THE STEM RUST COME FROM IN THE SUMMER?

We have already answered this question in part. It may come from barberry bushes wherever these occur. It has also been noted that air currents and the wind play an important part in the spread of the rust. There are only three ways known by means of which rust might appear in Manitoba in the summer. These are:

(1) From the red stage living over winter here.

(2) From the cluster-cup stage on the barberry.

(3) From being blown in from the south, where overwintering might have been accomplished in one of the first two ways.

It may be emphasized here that rust is not carried by the seed grain; that weather conditions alone cannot produce rust; that the black rust stage, and the spores produced from black spores, are functionless unless the barberry bush is present.

The red spores of rust may live on certain grasses such as wild barley until February or even March. A large number of tests made during the past three or four years have, however, shown that in every case the red spores examined were all dead before there were grasses or grains present in the spring for them to attack. In 1923 red spores brought in to the laboratory on wild barley on February 23 failed to germinate, although a few were found to be alive later. Red rust has not been found to live over

winter in the prairie provinces of Canada, nor in the tier of States immediately south of them.

The role of the barberry bush is discussed below. Regarding the third possibility, it cannot be denied that the wind plays an important part in the spread of rust throughout many parts of Western Canada. Rust may blow into Manitoba from Minnesota or North Dakota. Some of this rust may earlier have blown into Minnesota and North Dakota from States further south, where the red stage may have overwintered. But much of this stem rust in the States just south of us originated in the barberry bushes present there.

BARBERRY BUSHES AND STEM RUST

Farmers two hundred years ago noticed that rust was worse in fields near barberry bushes. Sixty years ago the reason for this was found in the fact that stem rust passes part of its life in the barberry. During the past few years a special effort has been made to eradicate barberries in various parts of the world. Denmark removed barberries in 1903, and has not had an epidemic of stem rust since. Since the barberry bushes were removed from England this rust is hard to find; only in Wales, where some barberries still remain, has the rust been abundant. It may be argued that conditions are quite different in this country, where the grain fields are larger and more continuous, and where the winds have a greater sweep; yet those who have studied the question believe that the thorough eradication of the barberry over the spring wheat area will result in much less rust. It is certain that rust is much worse near barberry bushes, and the general "conflagration" of rust may originate largely in the numberless little "fires" started from barberry bushes throughout the spring wheat area.

Fig. 8. The Noxious Weeds Act calls for the destruction of the Common Barberry (*Berberis vulgaris* and its varieties). This includes all the large, three-pronged, spiny-leaved varieties the purple leaved, the white, yellow, purple red and black berried kinds. Only the small-leaved Japanese varieties *B. thunbergii* are immune.

The common barberry (*Berberis vulgaris*) is a shrub formerly sold by nurseries as an ornamental plant. Barberry is not a native plant in this country, and has not been found to have escaped from cultivation in Manitoba. The Manitoba Noxious Weeds Act was amended in 1917 so as to include the barberry. Most of the barberries in the province have been eradicated. There remain a few, which should be destroyed.

Since rust is carried by winds, the removal of barberries in Minnesota, North Dakota and other States to the south is of interest and importance to Manitoba. In the five years ended December 31, 1922, 778,977 of these bushes were found in Minnesota, and 776,803

removed; all the 19,438 bushes found in North Dakota were removed. In the thirteen North Central States in which an active campaign is still in progress against the barberry, 5,829,368 bushes were found and 5,173,547 removed from April 1, 1918, to December 31, 1922. The work is expected to continue until all the bushes in these States are found and removed. It is obvious that this campaign against the barberry in the States can be expected to lessen rust in Manitoba, and we should make a special effort to help the work along by a thorough survey of the province to see that there are no bushes remaining, or no sprouts developing from previously removed bushes. See New Dominion Act, Page 19.

The small leaved barberry (*Berberis thunbergii*) does not rust, and may be safely planted.

THE FORMS OF STEM RUST ON DIFFERENT CEREALS AND GRASSES

The stem rust occurring upon wheat, oats, barley, rye and the various wild grasses looks much the same from each plant, and is all considered to be one species of rust. But the fungus is specialized in that it will not pass from wheat to oats or rye or vice-versa. The specialized forms of rust are called biologic forms, i.e., they differ in their biology or manner of life, although appearing similar in Morphology, or appearance. The following biologic forms are known from North America:

1. The Wheat form, *Puccinia graminis tritici*, attacks wheat, barley, and several wild grasses, including Western Rye Grasses (Agropyron), Wild Barley, Lime Grass, Wild Rye, etc., and the Barberry. This form is further specialized as is noted under the discussion of wheat diseases.

2. The Rye form, *Puccinia graminis secalis*, attacks rye, barley, and several wild grasses, including Quack Grass, Wild Barley, Lime Grass, etc., and also goes to Barberry.

3. The Oats form, *Puccinia graminis avenae*, attacks oats, several wild grasses, including Wild Oats, Orchard Grass, Crested Hair Grass, and the Barberry.

4. The Timothy form, *Puccinia graminis phlei-pratensis*, attacks Timothy, Orchard Grass, Crested Hair Grass, Fescue Grass, and Meadow Foxtail, but does not go to the Barberry.

5. The Red-top form, *Puccinia graminis agrostis*, attacks Red-top, Orchard Grass, and a few other wild grasses, sometimes appearing upon Couch Grass, and also goes to the Barberry.

It may be noted that all of the forms except the timothy form will develop on the barberry. The rust is not changed by passing to the barberry; it is limited to the same plants after growing on the barberry as it had been previously. Barley is attacked by either the wheat or the rye form; but the rust is not changed by growth on barley.

WILD GRASSES AND STEM RUST

Some of the wild grasses attacked by stem rust have already been noted. The following table lists only those species of wild grass so far found in Manitoba, and which are known to be attacked by stem rust, and gives the form of rust found upon them as far as reported by Stakman and Piemeisel.* When more than one form of rust occurs on a grass, the more important is placed first:

Scientific Name	Common Name	Form of Rust
Agropyron caninum	Awned Wheat Grass	Wheat
Agropyron dasystachyum	Northern Wheat Grass	
Agropyron repens	Couch Grass	Rye, Red Top
Agropyron Smithii	Western Wheat Grass	Wheat, Rye
Agropyron tenerum	Western Rye Grass	Wheat, Rye

*Stakman, E. C., and Piemeisel, F. J. Biologic forms of Puccinia graminis on cereals and grasses. Jour. Agr. Res. 10: 429-496, 1917.

Scientific Name	Common Name	Form of Rust
Agrostis alba	Red Top	Red Top
Agrostis hyemalis	Fool Hay	
Alopecurus aristulatus	Blue Foxtail	Red Top
Alopecurus pratensis	Meadow Foxtail	Oats, Timothy, Red Top
Avena fatua	Wild Oat	Oats
Beckmannia erucaeformis	Slough Grass	
Calamagrostis canadensis	Blue-joint	Oats
Cinna latifolia	Sweet Reed Grass	
Dactylis glomerata	Orchard Grass	Oats, Timothy, Red Top
Echinochloa crus-galli	Barnyard Grass	
Elymus canadensis	Canada Lime-grass	Wheat, Rye
Elymus Macounii	Macoun's Wild Rye	Wheat
Elymus virginicus	Virginia Lime-grass	Wheat, Rye
Festuca elatior	Tall Fescue	Timothy
Hordeum jubatum	Wild Barley	Wheat, Rye
Koeleria cristata	Crested Hair Grass	Oats, Timothy, Red Top
Muhlenbergia cuspidata	Prairie Rush-grass	
Muhlenbergia mexicana	Satin Grass	
Panicularia grandis	Tall Manna Grass	
Phalaris arundinacea	Reed Canary Grass	
Phleum pratense	Timothy	Timothy
Puccinellia tenuifolia	Slender Meadow Grass	
Sphenopholis obtusata	Early Bunch Grass	
Sporobolus cryptandrus	Sand Dropseed	Rye

It will be noted from the above list that a number of wild grasses in Manitoba may be attacked by stem rust. It may be seen, for example, that red rust will spread to orchard grass from oats, timothy, or red top, or from any other grass that bears these forms of rust; but the rust from oats is not changed by growing on orchard grass, or any other; it will not go subsequently to timothy for example.

Wild grasses, of course, help to spread rust; they provide more chance for the rust to develop. The destruction of such grass weeds as wild barley, wild oats, and couch grass is of value in lessening somewhat the spread of rust. But wild grasses are not the controlling factors in the development of rust.

THE PREVENTION OF RUST

Rust is not carried by the seed of grains; no method of seed treatment can lessen rust, except insofar as the treatment might make for earlier or stronger germination, and thus allow the plant to mature a little earlier. No method of spraying grain fields can be expected to be of value. A farmer cannot prevent rust by adding fertilizer or other chemicals to his soil; manure makes for rank growth and more rust unless the seed is sown thickly.

The rust problem will eventually, perhaps soon, be solved. There are two important undertakings now in progress: the barberry eradication campaign in the spring wheat area, discussed above, and work on the production of varieties of wheat (and other grains) resistant to rust. There is already a variety of winter wheat (Kanred), produced at the Kansas Experiment Station, which is resistant to rust; and much work is now being devoted toward making crosses and selections which will give a spring wheat with the quality of Marquis together with rust resistance. Winter wheat is not satisfactory for Manitoba.

The individual farmer can utilize certain practices which will lessen the severity of rust. Professor Ellis, in Manitoba Extension Bulletin 41, suggests the following:

1. Sow early, using good seed; this means earlier maturing.
2. Use early maturing varieties, provided they are otherwise good.
3. Sow thickly on rich soils, such as summerfallow.

4. Prepare a good seed bed, and sow at an even depth.
5. Do not harrow growing grain; it delays maturity.
6. The manure should be applied evenly and lightly.
7. Poorly drained areas, and soil drifting, usually mean more rust.
8. If rust is bad, the best time to harvest is at the stage when the grain is firm (i.e., when it cannot be crushed between thumb and finger); earlier or later cutting gives poorer results.

Further discussion of methods of lessening wheat rust are given in the section on wheat diseases.

LEAF RUST

Each of the four cereals may have a leaf rust as well as the stem rust. Leaf rusts do not attack the stems, although stem rust may attack the leaves. Leaf rusts often appear before stem rusts; the red stage is lighter or more orange or yellowish in color than is the red stage of stem rust; under the microscope the red spores of leaf rusts are seen to be roundish, whereas those of stem rust are elongated or oval; the black stage of leaf rusts is covered by the epidermis of the leaf, and is, therefore, less conspicuous than the black stage of stem rust. Leaf rusts do not go to barberry. The several leaf rusts are discussed under the crops they attack.

OTHER RUSTS

Many wild plants, such as roses, gooseberries, blue lettuce, golden rod, etc., are attacked by rusts. We have records of eighty different rusts in Manitoba. Only the ones mentioned in this bulletin, however, are found upon cereals in Manitoba.

PART II.

Cereal Smuts

It will be seen that each cereal crop grown in Manitoba has one or two smuts. Smuts may be divided into three classes:

(1) Those that can be prevented by formalin, bluestone, or other chemical seed treatment.

(2) Those that require a heat treatment of seed (hot water usually used) to kill the smut in the seed.

(3) Those (corn smut) that cannot be prevented by seed treatment.

Each cereal smut is limited to the one kind of grain.

Smuts of grains are distributed all over the world, and have long been known. Our cereal smuts attack the heads of grain, whereas rusts attack the stems and leaves. The black, smutty appearance of affected heads or other parts of plants is caused by the presence of millions of minute spores. These spores are roundish cells from one five-thousandth to one-thousandth of an inch in diameter. Usually these spores, upon germination, produce little stalks which bear other spores, but the loose smuts of wheat and barley produce only one kind of spore.

Bunt of wheat (sometimes called stinking smut, or covered smut), covered smut of barley, oats smuts, and certain other smuts, can be prevented by treating the seed with formalin, bluestone, or other chemicals. In these smuts the spores of the

Fig. 9

A—A head of Prelude showing 14 bunt balls. The stinking or covered smut of wheat.
B—The loose smut of wheat—has destroyed all the kernels.

fungus cling to the outside of the seed grain over winter; the grain becomes infected in the field, in the thresher, or in other handling. The smut spores can be seen on "tagged wheat" as a black smudge on the kernels, especially at the brush end. Tagged wheat is rejected by the elevators because it is unfit for bread making. When untreated seed bearing surface contamination with smut spores is planted, the smut spores germinate in the soil at the same time that the grain germinates, and produce small secondary spores which germinate and produce little "sprouts" which grow into the young seedling grain plants. As the cereal plant grows up, the smut grows up along with it without producing any conspicuous injury to the plant until it heads out. Then, instead of kernels of grain, there is produced the familiar smut. These smut spores subsequently become scattered over healthy grains.

SEED TREATMENT

Employment of formalin or formaldehyde solution (consisting of 40% of the gas dissolved in water) is the most commonly used treatment for smut. Formalin is inexpensive, safe, easy to handle, and one hundred per cent. efficient. The formalin solution may become milky in cool weather, but this milkiness disappears if water is added and the solution warmed.

There are several methods of using the formalin treatment. Some farmers use smut machines; these are satisfactory, though not necessary. Before treatment, wheat should be fanned to remove the "bunt balls" and light seeds. The formalin should be mixed at the rate of **1 pound** of 40% formalin to **40 gallons of water.**

The sprinkling method of treatment is commonly used. The grain to be treated is placed a few inches deep on a clean floor or wagon box, and sprinkled over with the diluted formalin solution. A sprinkling can is the best utensil, although a broom can be used for small quantities of grain. After the surface of the grain is sprinkled, it is quickly shoveled over, and then sprinkled again, and this repeated until all grains are moistened. **Forty gallons of solution will treat about forty bushels.** Finally the grain is piled up and covered with clean carpet, blankets, tarpaulin, or other cloth cover to keep in the fumes for 2 to 10 hours. Care must be taken not to put the treated grain into smutty sacks, bins, wagon boxes, etc.; these should be scrubbed or dipped also with formalin or other disinfectant. Grain should preferably be **sown soon after the treatment** is completed, the **seeder being set to allow for the swollen grain.** Grain must not be allowed to freeze when wet, nor to heat, sprout, or mold. Even if it is dried thoroughly after treatment, there is a possibility of some injury to some of the kernels from the formalin drying on the grains, but this injury is usually not sufficient to affect the stand of the crop. When grain is sown immediately after treatment there may be hastened germination from the swelling which has occurred before planting.

Another method of treatment with formalin is that of using barrels or other containers and immersing the seed. The seed may be left in sacks, dipped in, then pulled out and allowed to drain a moment, then dipped in again, and so on until the seed in the centre of the sack is wet ; it may then be left in the sacks 2 to 10 hours and then planted. Or the seed may be put loose into a barrel or vat and covered with formalin solution, and stirred (skim off any smut balls or light seeds that the fanning mill did not remove), then dumped out and covered as usual.

Bluestone is still used by some growers. It has the disadvantages of being hard to dissolve, it corrodes metal vessels, and is much more poisonous than formalin. It is not safe for anything except wheat. The formula used commonly in Manitoba is dipping the grain for a few minutes in one pound of bluestone (copper sulphate, blue vitriol) to 10 gallons of water or 4 lbs. per 40 gallon barrel. It may be dissolved by hanging it in a coarse sack near the top of the water. A safer treatment is a ten minute treatment in 1 lb. bluestone, 1 lb. salt, to 5 gallons of water, afterwards dipping for 10 minutes in milk of lime (1 lb. quicklime slaked in a little water, then water added to make 10 gallons). The formalin treatment, however, is to be preferred in Manitoba.

Tests were made by the Department of Botany at the Manitoba Agricultural College in 1922, to supplement tests previously made regarding the prevention of wheat smut by means of seed treatment. "Tagged" wheat was treated with formalin, 1 pint to 40 gallons of water, Bluestone dip, Dry Bordeaux (a mixture of bluestone and lime, ground fine and applied as a dust) bluestone dust with nicotine dust, copper carbonate (a fine dry powder) and the "Gas Grain Pickler" (a perforated gas pipe in a wagon box of grain, the gas being generated by heat and pumped throughout the grain in a pipe. Samples were taken from 6 sacks buried in the grain).

The results obtained are summarized in Table 1.

Table 1. Effect on Bunt of various seed treatments.

Treatment	No. of Bunt heads per 1/40 acre new land.	Treatment	No. of Bunt Heads per 1/40 acre new land.
None	237	Grain Gas Pickler: Sack	
Dry Bordeaux	226	No. 1 on top of grain, 24 ins. from pipe	117
Bluestone Dip	40	No. 2 on bottom of box, 18 ins. from pipe	198
Formalin	0	No. 3, 3 feet from tailboard, 12 ins. from pipe	147
Copper Carbonate powder	1	No. 4 in centre, 18 ins. above pipe	75
Bluestone and Tobacco dust	1	No. 5 on the pipe at the tailboard	123
		No. 6 on the pipe at the far end	118

The wheat used in the above test was a mixed smutty sample from Fort William. The plots were sown April 28. The results show perfect control from formalin. Nearly perfect control was also given by copper carbonate dust and by bluestone and tobacco dust. Copper carbonate offers considerable promise. It has given good results in Australia and in tests in the United States and elsewhere in Canada. It has the advantage of being dry, and thus does not cause swelling of the grain, and yet it adheres well

to the seed. Two or three ounces of copper carbonate dust are used for each bushel of grain, and the seed must be covered with powder by thorough shaking. This treatment and certain others which are being tested at the M.A.C. and elsewhere, must still be considered in the experimental stage, but appear promising.

The Field Husbandry Department at the M.A.C. has found good results regarding yield from the use of formalin. They report the following results:

	Yield per acre bushel
Wheat, untreated	26-⅝
Wheat, treated (formalin)	30-⅛

They find also that better yields are obtained after formalin treatment than after a bluestone dip, provided the grain is sown soon after treatment.

LOOSE SMUTS OF WHEAT AND BARLEY.

Loose smut of wheat cannot be prevented by the above treatments. Loose smuts can be recognized by the fact that the whole head, chaff and all, is destroyed, leaving only the bare stem. The smut spores blow in the field to healthy heads and there germinate at once and produce a slight infection within the seed. These seeds appear normal, and are perfectly satisfactory for bread making or other use. Upon planting, however, the smut grows up with the sprouting grain and eventually causes the loose smut on the heads of the grain. Growers must recognize the difference between the two kinds of smut on wheat and barley, and realize that the loose smuts may develop on seed treated with formalin, or bluestone, or other chemical. There is a considerable amount of loose smut in Manitoba, and fields showing as much as 10% of the disease have been seen. If a farmer has much loose smut, he should get good seed from some source free from loose smut. It is an excellent plan to grow a seed plot of wheat, and to remove all loose smut as soon as it appears in the plot.

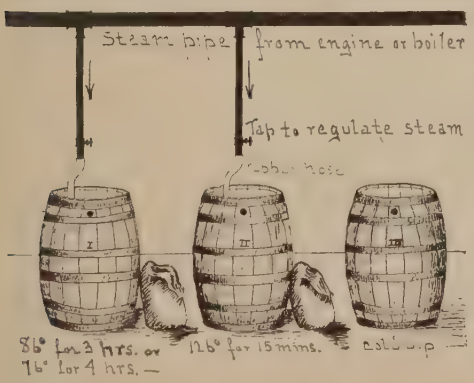


Fig. 10—Hot water treatment for loose smut of barley. For loose smut of wheat have the water in the centre barrel at 129 degrees F.

The loose smut of wheat can be prevented, if the seed is infected, only by the use of heat, since the smut is inside the seed. Loose smut of barley may be partially prevented by formalin treatment. For wheat the seed must be soaked in hot water at 129 degrees F. for 10 to 15 minutes, for barley 15 minutes at 126 degrees F. The seed must first be soaked in warm water for a few hours, as illustrated in the diagram (Fig. 10). The grain may be spread out to cool and dry after the treatment in the hot water.

This treatment is slow, and an absolutely accurate thermometer must be used. The treated seed should be tested for germination, and sown on an isolated seed plot to supply seed for the following year. If interested write to the Department of Botany, Manitoba Agricultural College, for further information.

PART III.

Diseases Listed by Crops

The following pages give further notes on rusts and smuts and other diseases of the various cereals.

WHEAT DISEASES

1. **Stem Rust,** caused by *Puccinia graminis tritici.* This rust, as previously mentioned, does not attack rye or oat fields, but does attack barley. It has recently been shown that no form of wheat rust attacks equally all varieties of wheat; the rust is further specialized in its growth upon wheat. Greenhouse tests at the University of Minnesota have shown that there are 37 forms of wheat rust.* The two commonest forms of rust so far found in Western Canada attack wheats and related plants as indicated in the following table (from Miss Newton†).

Variety of Wheat or Similar Plant	Kind of Attack Form XVII.	Kind of Attack Form XXIX.
Marquis	Heavy normal infection	Heavy normal infection
Kanred (a winter wheat)	Immune	Immune
Kota	Moderate susceptibility	Moderate susceptibility
Arnautka (durum)	Heavy infection	Mixed infection
Mindum (durum)	Heavy normal infection	Mixed infection
Speltz Marz	Heavy infection	Mixed infection
Kubanka	Heavy infection	Mixed infection
Acme	Moderate susceptibility	Moderate susceptibility
Emmer	Immune	Immune
Khapli (Indian Emmer)	Decided resistance	Very high resistance

Fourteen forms of wheat rust have been found in Western Canada, all of which have been found also in the United States. Six of these (including the two listed above) were found to constitute 70% of the collections. All six attack the various bread wheats similarly, and Kanred is immune to all the six. Efforts are now being made by plant breeders to produce a variety of wheat which combines the good qualities of Marquis with rust resistance. Meanwhile the continuance of the barberry eradication campaign should lessen the occurrence of rust in the spring wheat area, and certain methods that grain growers can utilize to lessen the seriousness of this disease have already been mentioned. Durum wheats stand rust and drought well, but are inferior to bread wheats, and lodge on heavy soils. Kota wheat is fairly resistant to rust, but weak in the straw. In general, Marquis wheat gives the best results over most of Manitoba in spite of its liability to rust.

2. **Leaf Rust,** caused by *Puccinia triticina* (*P. clematidis*). This rust is often abundant in Manitoba, and sometimes causes considerable damage. We estimated that it caused 2½% loss of wheat in 1921. But it is not nearly so serious as stem rust often is: the latter caused about 15% loss of wheat in 1921. The red spores of this rust live over winter here. It has recently been shown that the alternate hosts are certain species of Thalictrum (Meadow Rue) which grow in parts of Asia, the probable original home of wheat. The common rust of Meadow Rue in Manitoba goes to various wild grasses.

*Stakman, E. C., and Levine, M. N. The determination of biologic forms of Puccinia graminis on Triticum spp. Minn. Agr. Exp. Sta. Tech. Bull. 8: 1-10, 1922.

†Newton, Margaret. Studies in wheat steam rust (Puccinia graminis tritici). Trans Royal Soc. Canada, XVI., Sec. V. 153-210, 1922.

Eventually varieties of wheat resistant to this rust also may be developed; at present all that a farmer can do is to sow good seed, to sow early, and on well-prepared land, and in most years this rust will cause minor damage. Leaf rust of wheat will not attack other cereals.

3. **Bunt, covered smut** or **stinking smut,** caused by *Tilletia tritici*. Bunt is common in the province. In the older settled parts the disease is not serious, for seed treatment is commonly practiced. Figures compiled by the Agricultural Survey from the Dominion grain inspection branch records for 1918, 1919 and 1920 show that the percentage of cars of wheat rejected for smut in the area west of the Red River and south of a line running through Minnedosa varied from none to 0.5%, with a couple of municipalities showing figures a little higher, but reaching the maximum in Stuartburn municipality, where 25% of the cars were rejected for smut; 17% were rejected from Hillsburg municipality. These higher figures probably are explainable on the basis of the neglect of new settlers to treat their seed, and of moister soil conditions on new land, which allow more smut to develop.

Even though a farmer's wheat is free from this smut, it may become infected in threshing or other handling. The seed treatment is so cheap and simple that its use should be continued and extended.

Further south, bunt is more commonly caused by *Tilletia laevis*. This form of bunt has been found once or twice in Manitoba, and is quite similar in its effect on the head (the plant is not so much stunted by this smut) and the treatment is the same as for our common bunt.

4. **Loose Smut,** caused by *Ustilago tritici*. There is considerable loose smut throughout Manitoba. It is easily recognized in the field by the bare blackened stalk that remains after the head is destroyed. Ordinary seed treatment will not prevent it. If growers find that they have loose smut in their wheat, they should try to get good healthy wheat free from this smut. The hot water treatment, previously mentioned, may be used for the elimination of this smut from wheat.

5. **Blights**, caused by *Helminthosporium* spp. The death or stunting of wheat in the seedling stage, injuries to the nodes, leaf spotting, blackening of the tips of kernels, and some of the poor filling of the heads, may be caused by species of *Helminthosporium*. This fungus may live over winter in the soil, or be carried by the seed. Durum wheats were especially severely attacked at the College in 1921. These troubles can be lessened by seed treatment, crop rotation and other good agricultural practices.

6. **Scab** or **"Pink Heads,"** caused by *Gibberella saubinetii*. Scab is one of the worst wheat diseases in warmer and moister regions in the United States. This disease will probably not prove serious in Manitoba, although considerable of it is present some years. Affected heads ripen prematurely and become whitish, then often become pink from the growth of the fungus. The seeds are shrivelled and pale in color. Seedling blight may occur when affected seeds are planted. In the corn belt this fungus also attacks corn, causing root rotting and stunting of the plants, but corn has not been found affected in Manitoba. Ruby wheat showed considerable infection with scab at M.A.C. in 1921. The use of healthy plump seed, seed treatment and crop rotation are methods which will lessen the danger of attack by this fungus.

7. **White Tip,** caused by weather conditions. In hot, dry, windy weather the tip of the developing wheat heads may fail to fill and turn white. It is sometimes quite prevalent in the drier areas of Manitoba. Nothing can be done to prevent this, except the utilization of methods of farming which tend to conserve the water supply.

8. **Ergot,** caused by *Claviceps purpurea*. This disease is very common on rye, and

seldom causes injury to common wheats. Durum varieties seem to be particularly susceptible, however. See discussion under rye.

MINOR DISEASES OF WHEAT

9. **Black Chaff,** caused by *Bacillus translucens undulosum.* This disease is occasionally found as a blackening of the chaff of the heads. It is not serious.

10. **Glume** and **Leaf Spots,** caused by *Septoria* sp. The chaff is also blackened in this disease, but with small black pin-point dots present in the blackened spots. The leaves may also bear spots caused by this fungus. The trouble is not serious in Manitoba.

11. **Rotting** or **Moulding** of the heads in the stook frequently occurs when the fall is rainy. Considerable damage may be caused. It is obvious that efforts must be made not to allow the bundles to remain wet for prolonged periods.

12. **Basal Glume Rot,** caused by *Bacterium atrofaciens.* Some damage is reported by Prof. Fraser from Saskatchewan; but we have not found this disease as yet in Manitoba. The base of the chaff is blackened and somewhat rotted.

13. **Flag Smut** attacks stems or leaves; it was found a few years ago in Illinois, but is not likely to occur in Manitoba. This smut can also be prevented by seed treatment.

OATS DISEASES

1. **Stem Rust,** caused by *Puccinia graminis avenae.* Stem rust may appear on oats as early in the season as it occurs on wheat, and may cause considerable damage. White Russian oats are very resistant. See also the previous discussion of rust.

2. **Leaf Rust** or **Crown Rust,** caused by *Puccinia Rhamni* (*Puccinia coronata*). This rust is common on the leaves and sheaths of oats in Manitoba. The clustercup occurs commonly on the buckthorn sometimes planted as a hedge plant. This rust is also found upon blue joint, wild oats, and other wild grasses. It is called crown rust because of the crown-like prongs which occur at the top of the black spores. It differs from stem rust in that it produces orange colored masses of red spores, and the black stage remains covered by the epidermis of the leaf. This and other rusts are worse on grain that has rank growth, that is lodged, or sown on poorly drained areas. Crown rust is also worse in the vicinity of buckthorns. Green Russian oats are considered resistant, but are late in maturing. Very early varieties may escape this rust.

3. **Smuts,** caused by *Ustilago avenae* and *U. levis* There are two smuts of oats to be found in Manitoba, differing slightly in the appearance of the spores and in the effect upon the head, but both are prevented by formalin or other seed treatment. Oats are easily injured by bluestone, so this treatment should not be used. The ordinary formalin treatment, however, is generally satisfactory and easily applied. Since formalin may injure Liberty or Hulless oats, copper carbonate or other compound may prove more satisfactory for this variety.

4. **Spikelet Sterility,** characterized by the absence of kernels in some parts of the oats head, is brought about by weather and soil conditions unfavorable to the development of the plant. It is not a serious trouble, is not spread from plant to plant, nor carried by the seed.

Seedling blights, root rots and **leaf spots** may cause some damage to oats, much as in the case of wheat. The use of seed treatment, crop rotation, and other good agricultural practices tend to lessen these troubles.

RYE DISEASES

1. **Stem Rust,** caused by *Puccinia graminis secalis,* may often be found upon rye, but the crop usually matures before much damage is produced.

2. **Leaf Rust,** caused by *Puccinia Asperifolii* (*P. dispersa*) is common on rye, but also usually does not cause much injury. This rust attacks only rye in Manitoba.

3. **Ergot,** caused by *Claviceps purpurea*. Ergot is familiar as a purplish-black body replacing the rye kernels. The life history of this fungus has already been outlined. The rye heads are attacked while they are in bloom. Damage is caused not only by the loss of rye kernels that are replaced by ergot, but also by the blighting of kernels even when ergot bodies do not occur. Ergot is poisonous if taken in quantity by stock or people. Ergot is even more common on various wild grasses than it it on rye. These wild grasses around rye fields should be cut before the heads mature sufficiently to show ergot. Durum wheat is also affected. The ergots overwinter principally on the soil, where they fall from the rye or grasses. Crop rotation should be practiced. Ergots may be floated from rye seed by immersing in a 20% solution of common salt. Ergot is conspicuous, but does not cause any great loss of rye in Manitoba.

4. **Rye Smut,** caused by *Urocystis occulta*. This smut has not yet been found in rye fields throughout Manitoba. The stems and leaves, as well as the head, may be attacked. Formalin treatment will prevent it.

Certain other troubles, such as **seedling blights, root rots, spikelet sterility, powdery mildew, leafspots, winter injury,** etc., may be sometimes found in rye, but in general this cereal is not seriously affected by plant diseases.

BARLEY DISEASES

1. **Stem Rust,** caused by *Puccinia graminis tritici* or *P. graminis secalis*. Barley is attacked by either the wheat or rye form of stem rust. Barley is very susceptible to rust. Early sown barley may, however, escape damage. See previous discussions of rust.

2. **Leaf Rust,** caused by *Puccinia anomala*. This has so far been found only once in Manitoba, and causes no damage.

3. **Covered Smut,** caused by *Ustilago Hordei*. This smut is quite common in Manitoba. The kernels and the chaff are both attacked, but the smut remains covered by a membrane until after harvest. The masses of spores are black or purplish black. Formalin treatment prevents this smut, and certain other barley diseases, and thereby allows often a marked increase in yield. Formalin is the best treatment for barley.

4. **Loose Smut,** caused by *Ustilago nuda*. In this smut the powdery, olive-brown mass of spores replacing the kernels and chaff usually blows away before harvest. While the hot water treatment is necessary to kill this smut entirely, yet it may be reduced by consistent use of the formalin treatment. If this smut is serious, it would often be advisable to obtain seed from healthier fields.

5. **Stripe,** caused by *Helminthosporium gramineum*. Stripe produces long brownish or yellowish streaks on the barley leaves. It is very common, and often causes considerable damage. The barley seed should be treated with formalin.

6. **Spot Blotch, Seedling Blights** and **Net Blotch,** caused by *Helminthosporium sativum, H. teres.* and other species. Considerable damage may be caused by these fungi. Blotches appear on the leaves, and the seedlings may be blighted. The chaff and straw may also be affected, the leaves may turn brown, and the yield is usually reduced. Manchuria barley is quite resistant to much of this trouble. Healthy seed, seed treatment with formalin, and crop rotation should be used.

CORN DISEASES

Corn, of course, is liable to be injured by frost and cool weather in this climate. It is not seriously attacked by fungous diseases here.

1. **Corn Smut,** caused by *Ustilago zeae.* This is a conspicuous disease, which causes some damage. Seed treatment is useless, because the spores are not carried by the seed, but may live over winter in the soil, or in manure piles. The spores are soon killed in the silo. Crop rotation should be practiced, and care used in the application of manure containing corn smut to fields which are to produce corn.

2. **Rust,** caused by *Puccinia sorghi.* This disease occurred quite commonly in 1921 and 1922 on the leaves, but causes no damage here.

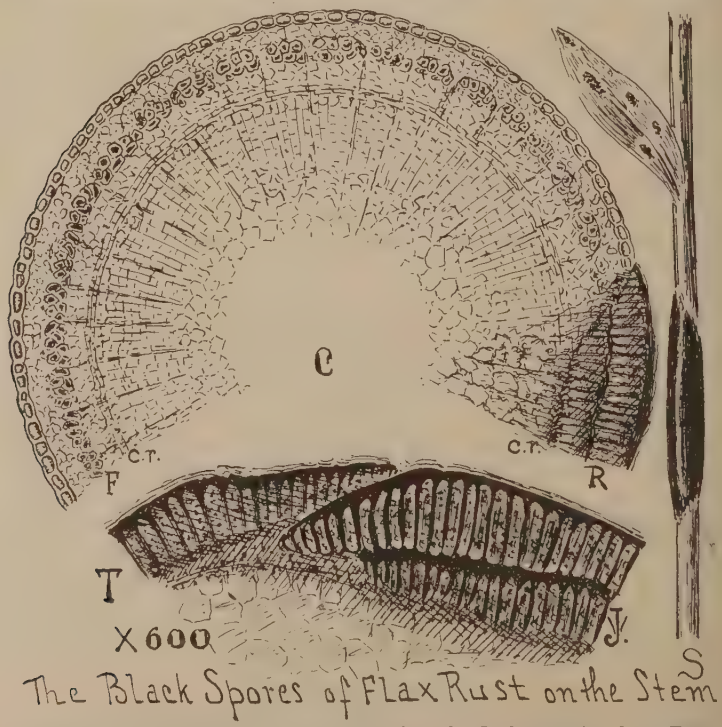
3. **Ear Rots,** caused by various fungi, sometimes are found. Affected ears should not be used for seed. Root rots have not yet been found in the province.

4. Corn and other silage may be destroyed, or sometimes rendered poisonous to stock, by **moulds** growing on the silage. The silo should be air tight, and the silage well packed, so that moulds will not develop. Mouldy silage, such as that found at the top of the silo, or in "pockets" within the silo, should not be fed. It is a good plan to cover the silage with hay to prevent some of the moulding of the silage at the top.

FLAX DISEASES

1. **Flax Rust,** caused by *Melampsora lini.* This rust, which attacks the stems and leaves, may cause injury to fibre flax, and sometimes lessens the seed production. Certain flax varieties (such as Premost) are resistant to the disease.

2. **Flax Wilt,** caused by *Fusarium lini.* This disease may cause serious damage, especially when flax is sown a second year on the same land. Wilt resistant varieties can be obtained, and such seed should be used at least on anything but new breaking.



S—Flax stem with black spores and red spores on the leaf. C—Cross section of stem X 100 showing fibres (F) destroyed by black spores at R. T—Black spores X 600, two layers deep.

FORAGE CROP DISEASES

There is not space here for a detailed discussion of forage crop diseases. In general, these crops are not very seriously attacked by plant diseases in Manitoba. Alfalfa leaf spot is quite common, but usually not serious. Sunflowers may lose some of their leaves from rust, and a stem rot has been found in the Province, but neither disease is especially serious as yet.

New Dominion Act re Barberry and Buckthorn

Amendment No. 4 (June 4, 1923)

By Order-in-Council dated June 4, 1923 (P.C. 1001), the amendment dealing with the importation into the Prairie Provinces and eradication therein of certain species of *Berberis*, passed on April 19, 1919, as Subsection (a) of Section 1e of the Regulations, was rescinded and the following substituted therefor:

"(a) European Buckthorn (Rhamnus cathartica L.) and the following species, hybrids and horticultural varieties of the genera *Berberis* and *Odostemon* (Mahonia), including:

B. vulgaris L.
B. amurensis Rupr.
B. canadensis Pursh.
B. lycium Royle.
B. sibirica Pall.
B. aristata D.C.
B. ilicifolia Forst.
B. nepalensis Spreng.
C. aquifolium Rudb.

Constituting an obstacle to the successful control of Crown Rust of Oats and Black-stem Rust of Wheat respectively, shall, therefore, be prohibited from being moved from any area outside to any area within the Provinces of *Manitoba, Saskatchewan and Alberta*, throughout which Provinces *they shall be exterminated without any claim for compensation.*"

The only change in this Regulation is the addition of European Buckthorn (Rhamnus cathartica L.) which constitutes an obstacle to the successful control of Crown Rust of Oats.

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jurious or fatal. Th[illegible]s of securing valuable new plants through mutation are therefore small.

All lethal f[illegible]ned only in the heterozygous condition because the pure form [illegible] lethal factors will therefore not breed true. The factors [illegible]t ways. They may cause the death or failure of [illegible]ture. Or when the gametes function properly [illegible]many ways.

[illegible]ther than lethal ones. Probably ma[illegible] other effect (such as dwarf- ir[illegible]ses absence of the plants wh[illegible]ditions.

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If in any individual b[illegible] different lethal factor the ind[illegible] lethal. In every generation resu[illegible] kinds will die, and hence only the h[illegible] therefore, is a condition of permanent hy[illegible]

Potato seed treatment tests in Manitoba. G. R. Bisby.

Four years' tests have shown that black scurf begins to develop on potato tubers at Winnipeg ordinarily during August, and accumulates in increasing amounts through September. There is a variation from year to year in the amount of scurf at a given date, but digging as soon as the potatoes are mature lessens the percentage of black scurf. Neither corrosive sublimate, copper sulphate, copper carbonate, nor semesan exerted any noticeable "residual effect" in preventing the development of sclerotia arising from the fungus in the soil. Semesan may increase the yield somewhat. Both inoculated and non-inoculated sulphur reduced scab, but did not lessen black scurf, and sulphur was not found to be practicable. The potato scab organism may be very abundant in virgin Red River soil. The various seed treatments nevertheless gave better results with scab than with black scurf.

* * *

Potato Diseases

G. R. BISBY

Manitoba Agricultural College, Winnipeg

Western Canada is free from several potato diseases which cause much damage in various other parts of the world. There are, nevertheless, several diseases which are very prevalent here, and few crops respond so favourably as does the potato to measures tending toward the reduction of diseases.

The writer's experience with potato diseases in Western Canada has been principally limited to Manitoba, and a summary of these diseases has recently been published as Manitoba Extension Bulletin 66. This note attempts only to summarise a few more important considerations.

Of the potato diseases found in the prairie provinces, leaf roll and mosaic are among the worst. They are characterised by mottled, crinkled, or rolled leaves, by stunting of the plants, and by reduced yields. They are transmitted by planting tubers from affected plants, and are spread in the summer from plant to plant by aphids. Recent work by plant pathologists indicates that protozoa are responsible for these diseases and others of the mosaic type.

Rhizoctonia is very prevalent, and causes damage from injury to the sprouts before they appear above ground, from dry stem rot of older stems, and black scurf upon the tubers. Common scab is also a serious disease in many localities.

The leaves of potatoes may show some spotting from early blight and tipburn, but late blight appears to be absent from the three prairie provinces.

Blackleg is fairly common in moist and cool seasons, and is recognised by the inky-black rotting of the lower stem, and sometimes of the tubers also. Another disease which may be found is wilt. Wilt is usually found only rather late in the season. The tubers may show a browning at the stem end, but this is not generally serious.

Dry rot causes considerable loss to potatoes stored during the winter. There are also several other diseases which may be found upon or within the tubers. These include frost injury, hollow heart, black heart, net necrosis and spindling sprout. These troubles are not serious as a rule.

For the prevention of loss from potato diseases it is important that good seed, preferably certified seed, be obtained, and care given the seed and crop. The use of a seed plot gives exceptionally favourable results with potatoes, and allows for the removal of certain diseases during the summer. The best seed for a seed plot the following year may be obtained by hill selection from the seed plot.

Seed treatment with formalin, 1 pound to 24 gallons of water, or with corrosive sublimate, 4 ounces to 24 gallons of water, kills the scab, much of the black scurf and other germs upon the surface of the tubers. The potatoes should be treated about two hours in the formalin solution and one and a half hours in the sublimate solution. It must be remembered, however, that scab and rhizoctonia may live in the soil, so that treatment is not a guarantee of a clean crop.

Spraying the vines with Bordeaux mixture has given good results in Manitoba. Early blight and tipburn are lessened and certain insects are repelled. Poison must, however, be applied or added to Bordeaux when the Colorado beetle is present.

The Milling Value of Saskatchewan Wheats

By C. H. GOULDEN

University of Saskatchewan, Saskatoon

Introduction

Since Saskatchewan produces such a large proportion of the Canadian wheat crop it is of considerable economic importance to the farmers that the quality standard of the wheat produced be kept high. At present, the hard red spring wheats grown in the Western provinces are noted for the flour of high baking strength which may be milled from them. For this reason the flours from these parts are much used for blending with weaker flours obtained from wheats grown under more humid climatic conditions. This does not mean that the quality of our wheat cannot be improved; nor does it mean that the Western provinces produce no wheat of very poor quality. As will be noted later, it appears quite probable that the quality of grain obtained from even our best varieties may be distinctly improved by systematic selection and testing. We must admit furthermore, that owing to unfavourable climatic conditions in certain parts, and to the use of varieties producing grain of inherently poor quality, a goodly proportion of the wheat grown is decidedly inferior from the milling and baking standpoint.

As agronomists we are interested chiefly in the improvement of wheat quality by advocating the use of only those varieties that produce grain of proven excellence for milling purposes. It is to this end that most of the work done by the Field Husbandry Department on the milling and baking value of wheats has been directed

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FUNGI FROM CENTRAL MANITOBA

G. R. BISBY

"Norway House" is the name applied specifically to a post of the Hudson's Bay Co., and generally to an area on or near 54° north latitude and about 97° 50′ west of Greenwich. This region is along the Nelson River just north of Lake Winnipeg, and is some 350 miles north of the International Boundary, and about 300 miles from Hudson's Bay. It is near the geographical center of Manitoba, about the center of Canada in an east and west direction, and is approximately half way between a parallel passing through Pittsburgh and Lincoln, and the Arctic Circle. Norway House lies just within the geologically ancient Laurentian Plateau, and the Pre-cambrian rock is either exposed or lightly covered with soil. At first glance the plants and the rock formation resemble those found near the Lake of the Woods and north of Lake Superior. The trees are, however, somewhat smaller than they are three hundred miles southeast, and various species of plants found near the Lake of the Woods are missing from the Norway House region. Black spruce, jack pine, larch, poplars, birches, willows, and *Prunus* spp. are the common trees. Lowe[1] has listed the higher plants of an area a few miles from Norway House.

Norway House is within an enormous area of central Canada in which few surveys for fungi have been made. The fungi of southern Canada and the northern United States are moderately well known, and the fungi of the Arctic regions, including Alaska, Greenland, and the northern coast of Canada, have also received considerable attention.[2]

The nearest agricultural area is the Swan River Valley some 200 miles from Norway House, and the latter region is not much affected by civilization, although some potatoes, vegetables, sunflow-

[1] Lowe, C. W., The Flora of Warren's Landing, Lake Winnipeg, Man., Canadian Field-Nat. 34: 26–30, 1920.

[2] See Dearness, John, Report of the Canadian Arctic Expedition 1913–1918, Vol. IV, part C, pp. 1c–24c, 1923, for list of fungi and for references.

ers, timothy, and oats are grown, and these plants yielded certain of the fungi reported here.

The writer submitted various specimens to specialists, both in order to obtain accurate determinations, and in order to place specimens in herbaria where they would be useful as indicating the range of fungi. The names of those to whom fungi were sent are indicated below; to all of them the writer is grateful, and also to Professor V. W. Jackson for certain host determinations, and to Dr. A. H. R. Buller for examining certain fungi and for other help.

Norway House, with the nearby Rossville Mission Indian School, and the new Playgreen Inn at which to stay, is a splendid spot to spend a summer holiday; especially for one interested in the fungi. The 118 species here reported were all collected in the six days from Aug. 11 to 16, 1923. The range of several species of fungi is extended considerably northward.

It is still a common practice to designate simply "Canada" in giving distribution of fungi. Since Canada is about the size of the United States and Mexico combined, and extends from a peach belt at 42° latitude nearly to the North Pole, and from the 57th to the 141st meridian, it is evident that the name of the province or other destination should be given.

MYXOMYCETES

The slime molds were not abundant. The two marked "E" were determined by Dr. W. T. Elliott, Tanworth-in-Arden, England.

Craterium leucocephalum (Pers.) Dittm., *1630* E.
Didymium squamulosum (A. and S.) Fr., *1631* E.
Enteridium Rozeanum (Rost.) Wing, *1632.*

BACTERIA

The following bacterial diseases of plants were found:

Actinomyces scabies (Thaxt.) Güssow, common on potatoes, *1437.*
Bacillus atrosepticus van Hall. An occasional potato plant was found affected.
Pseudomonas Phaseoli, E. F. Sm., common on beans, *1448.*

PHYCOMYCETES

Rhizopus nigricans Ehr. Found on leaf mold. This was the only Phycomycete encountered. Dearness (l. c.) comments on the rarity of Phycomycetes in more arctic regions.

ASCOMYCETES

Numbers followed by "S" are identifications made by the courtesy of Dr. F. J. Seaver, New York Botanical Gardens.

Chlorosplenium aeruginosum (Oed.) De Not. on old wood, *1439.*

Claviceps purpurea (Fr.) Tul. on *Poa pratense, 1401;* on *Elymus innovatus, 1412;* on *Agropyron* sp. *1413.*

Daldinia vernicosa (Schw.) Ces. and De Not. on old wood, *1438.*

Diatrype spp. *1411* S, *1413* S.

Eleutheromyces subulatus (Tode) Fuckel, on a mushroom, *1480* S.

Erysiphe graminis D. C. on *Phleum pratense, 1427.* Perhaps it was too early for powdery mildews; only two were found.

E. polygoni D. C. on *Polygonum aviculare, 1443.*

Helotium citrinum (Hedw.) Fr. on wood, *1435.*

Hypoxylon fuscum (Pers.) Fr. *1415* S.

H. multiforme Fr. *1410* S, *1412* S.

Hysterium sp. on coniferous wood, *1405.* An interesting species with spores 4–6 by 34–43 μ. Not yet definitely determined.

Lophium mytilinellum Fr. I am placing as this species No. *1603* with hysterothecia 0.2–0.4 mm. long, and spores 1.5–2 by 90–120 μ. It was found on the bark of a coniferous tree.

Lophodermium pinastri (Schr.) Chev. on leaves of *Pinus Banksiana, 1404.*

Nectria cinnabarina (Tode) Fr. (*Tubercularia vulgaris* stage) *1414* S.

Peziza vesiculosa Bull. *1419.*

Rhytisma salicinum (Pers.) Fr. on willow leaves, *1411.*

Spathularia clavata (Schaeff.) Sacc. on old wood in mossy ground, *1408.*

FUNGI IMPERFECTI

Leaf spots were common. Numbers marked "D" were examined by Dr. J. J. Davis of Wisconsin.

Alternaria Solani (E. & M.) J. & G. on potatoes, *1418*. No spores were found but the spots were typical of early blight.

Cercospora antipus Ell. & Hol. on *Lonicera glaucescens, 1483*.

C. zebrina Pass. on *Trifolium repens, 1446*.

Cladosporium (probably *C. graminum* Corda) on *Poa pratense, 1402;* on oats, *1429*.

C. subsessile Ell. & Barth. on *Populus tremuloides, 1623*.

Cylindrosporium hiemale Higgins on *Prunus pennsylvanicus, 1444*.

C. lutescens Higgins on *Padus virginiana, 1606*.

Fusicladium radiosum (Lib.) Lindau on *Populus* leaves, *1434* D.

Phyllosticta Caricis (Fuckel) Sacc. on old leaves of *Carex vesicaria, 1628*.

Polythrincium trifolii Kze. on *Trifolium repens, 1447*.

Ramularia punctiformis (Schl.) v. Hoeh. on *Epilobium angustifolium, 1485*. The spores were found to be 18–26 by 3–4 μ, which is somewhat large for this species.

R. Taraxaci Karst. on *Leontodon Taraxacum, 1400*.

R. Tulasnei Sacc. common on leaves of *Fragaria canadensis, 1430*.

Rhizoctonia Solani Kuehn, common on potato stems and tubers, *1417*. This fungus is evidently common in this region; the *Corticium* stage was found twice on old wood.

Septoria alnifolia E. & E. on *Alnus incana, 1481*. Spores rather long, being 54–70 x 3 μ, but probably this species.

S. caricis Passer. on *Carex vesicaria, 1626*. The spores are 35–40 x 2.5 μ and fit this species, but I am not sure it occurs in North America.

S. Ribis Desm. common on *Ribes* spp. *1433*.

S. salicina Pk. (probably) on *Salix* spp. *1431* D.

Stagonospora sp. on *Carex vesicaria, 1626*.

BASIDIOMYCETES

Ustilaginales. Only the following three smuts were found at Norway House, and one of these was introduced. The smuts are rare in the arctic regions further North.

Cintractia Caricis (Pers.) Magn. on *Carex aquatilis,* common, *1406*.

Ustilago levis (K. & S.) Magn. on *Avena sativa, 1445*.

U. Lorentziana Thuem. on *Hordeum jubatum.* Very common, *1428.*

Uredinales. The rusts are apparently rare in arctic regions, but as far south as Norway House they are evidently quite numerous.

Coleosporium Solidaginis (Schw.) Thuem. Common on *Solidago multiradiata, 1415.*

Melampsora Bigelowii Thuem. on *Salix* spp. common, *1432.*

Melampsoropsis ledicola (Peck) Arth. I common on *Picea mariana, 1604;* II on *Ledum groenlandicum, 1403.* This rust determined by W. P. Fraser.

Phragmidium Rosae-acicularis Liro, II, III on *Rosa acicularis, 1407.*

Puccinia epiphylla (L.) Wettst. II common on *Poa pratensis, 1416.*

P. gigantea P. Karst. III on *Chamaenerion angustifolium, 1605,* det. H. S. Jackson. This extends the range considerably eastward.

P. graminis Pers. Especial attention was paid to the occurrence of this rust, because of the data it would give on the spread of the urediniospores by the wind. At Beren's River, half way up Lake Winnipeg, this rust was already abundant on Aug. 9 on a small patch of oats and on *Hordeum jubatum.* At Grand Rapids on Aug. 10 no *P. graminis* could be found. At Norway House rust was common but not serious on timothy, *1424;* this form evidently overwinters there in the uredinial stage. Hundreds of *Hordeum jubatum* plants were examined before a couple of pustules of primary infection were finally found at Rossville Mission on Aug. 14, No. *1425.* Two or three pustules were found at the same date and place on a plot of oats, *1423.* The *Avenae* and the *Tritici* or *secalis* forms had apparently just reached the Norway House region in time for early infections to appear by the middle of August. The early and continuous protection of the uredinial stage in autumn and winter by snow, and the sudden spring, might appear to favor overwintering of this stage; but evidently only the timothy form lives over winter there. On the return trip, rust was found on Aug. 17 on *Hordeum jubatum* at Grand Rapids, *1397,* and in increasing quantities as we went south.

P. Grossulariae (Schum.) Lagerh. I on *Ribes* sp. *1450.*

P. Helianthi-mollis (Schw.) Jackson II, III on *Helianthus annuus* (cult.), *1426.*

P. lysimachiata (Schw.) Kern I on *Naumburgia thyrsiflora, 1409.*

P. urticata (Link) Kern on *Carex* sp. *1629.*

Pucciniastrum arcticum (Lag.) Tranz. on *Rubus triflorus, 1410.*

P. pustulatum (Pers.) Diet. on *Chamaenerion angustifolium, 1449.* Determination verified by W. P. Fraser.

Tremellales. All fungi marked "Ll" here and elsewhere were determined by Mr. C. G. Lloyd.

Exidia glandulosa (Bull.) Fr. *1442.*

Tremella lutescens Fr. *1622* Ll.

T. mesenterica Fr. *1621* Ll.

AGARICALES

THELEPHORACEAE and HYPOCHNACEAE (on old wood unless otherwise noted). All numbers marked "B" were identified by Dr. E. A. Burt.

Corticum arachnoideum Berk. *1465* B and *1466* B.

C. laetum Karst. *1460* B.

C. livido-caeruleum Karst. *1462* B.

C. vagum B. and C. *1475* B, *1477* B.

Hypochnus cervinus Burt. *1457* B.

H. fumosus Fr. *1459* B.

Peniophora glebulosa Bres. *1458* B, *1476* B.

P. subalutacea Karst. *1464* B.

Stereum fasciatum Schw., *1451* B.

S. rufum Fr. common on fallen poplar branches, *1436* B.

S. ochraceoflavum Schw., det. by C. H. Kauffman.

S. rugosiusculum B. & C. *1452* B. According to F. T. Brooks, the same as *S. purpureum.*

Thelephora caryophyllea (Schaeff.) Fr. *1454* B.

T. intybacea (Pers.) Fr. *1455* B.

T. terrestris (Ehrh.) Fr. *1453* B, *1470* B.

Clavariaceae: Clavaria ligula Schaeff. *1468* B.

C. pulchra Pk. on ground, *1469* B.

C. stricta Pers. on decaying wood, *1474* B.

Hydnaceae: Hydnum caeruleum Fl. Dan. *1471* B.
H. connatum Schultz (*H. cyathiforme* Schaeff.) *1473* B.
H. mirabile Fr. (probably) *1472* B.
H. repandum Fr. Found but not preserved.
Odontia spp. *1494* V, *1463* B.

POLYPORACEAE. Dr. L. O. Overholts reported on those fungi marked "V."

Daedalea unicolor Bull. *1486* V, *1499* V.
Favolus canadensis Klotz, *1420* V.
Fomes fomentarius (L.) Gill. *1491* V.
Lenzites betulina Fr. *1495* V.
L. saepiaria Fr. *1496* V, *1497* V.
Merulius niveus Fr. *1461* B.
M. pilosus Burt. *1456* B, *1467* B.
Polyporus betulinus Bull. *1421* V, *1422.*
P. biformis Kl. *1490* V.
P. caesius Fr. *1492* V.
P. pargamenus Fr. *1489* V.
P. pubescens Schum. (or possibly var. *Grayii* according to Dr. Overholts), *1487* V.
P. tulipiferus (Schw.) Overh. (probably) *1498* V.
Trametes carnea Nees, *1600* V.
T. hispida (Bagl.) Fr. *1601* V.

BOLETACEAE. *Boletus scaber* Fr. occurred commonly, and also half a dozen other species which I could not identify with certainty.

AGARICACEAE. Gill fungi were abundant at Norway House during my stay there, since I chanced to strike a period of fine weather following rains. I had neither time nor facilities, however, to handle them, and could only dry a few of them, and Dr. Kauffman kindly looked these over; he reported those marked here with "K" as being forms of which he felt sure of the identification. Those not marked were identified by the writer in the field.

Cantharellus aurantiacus Fr. K.
C. umbonatus Fr. K.
Clitocybe laccata Quél. K.
Coprinus micaceus Fr.

Cortinarius calochrous Fr. K.
Crepidotus herbarum Pk. K.
Flammula sapinea Fr. K.
Inocybe minima Pk. K.
Lactarius parvus Pk. K.
L. torminosus Fr. K.
Naucoria pediades Fr.
Panaeolus solidipes Pk.
Russula chamaeolentinus Fr. K.
R. emetica Fr.
R. graminicolor Quél. K.

LYCOPERDALES

Lycoperdon cepaeforme Bull. (?) *1609* Ll.
L. spadiceum Pers. (?) *1607* Ll.

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The Sclerotinia Disease of Sunflowers and Other Plants.

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The fungus causing stem rot of sunflowers, and diseases of several other plants, has been kept under observation in Manitoba since 1920. An account of the disease was given in this journal in 1921 (2). This disease on sunflowers has attracted attention also in British Columbia (5) Ontario (7), Quebec (1), New Brunswick (3), and it is also reported from Alberta and Prince Edward Island (14). It has also been found in several of the States, and is especially troublesome in Montana (15). Baribeau (1) has given a good account of the disease in Quebec. This Sclerotinia is characterized by the production on all crops attacked of black, hard, oval or irregular bodies, called sclerotia, and it can usually be recognized by these.

In view of the fact that uncertainty existed as to the extact species of Sclerotinia which was causing the trouble, attempts were made to germinate the sclerotia and produce apothecia and ascospores. While Cunningham (3) records as *S. Libertiana* Fcl. the fungus which attacked various vegetables as well as sunflowers, he does not mention having obtained apothecia, although he doubtless had obtained them from sclerotia from at least some of the vegetables with which he worked. Baribeau (1) did not succeed in obtaining apothecia. In most cases the fungus is reported as "Sclerotinia sp." or "probably *S. libertiana*". Mrs. Jones (8), however, obtained asci and spores from sclerotia produced on sunflowers in Wisconsin, and concluded that the fungus was *S. libertiana.* Miss Wakefield (16) points out that *S. sclerotiorum* (Lib.) Massee is a prior name which should be used for this fungus.

Sclerotia from sunflowers placed in damp chambers either before or after exposures to periods of freezing or placed in sand and buried outside over winter either did not germinate, or produced only mycelium. However, sclerotia from the exterior of the underground stems of sunflowers left in the field over winter were found to be showing stipes in May of 1924, and these were brought in and placed in damp sand in Petri dishes. The stipes continued to grow, turning sharply toward the light; after a time they were moved near a window, and the covers of the dishes partly opened, whereupon good apothecia were obtained (Platel, Fig.1). Spores were shot out in clouds when the covers were opened. The spores in the fresh condition were found to be 10 - 12½ (occasionally to 14) by 5 - 6½μ, and the asci 100 to 150 by 8 to 10μ. The smaller measurements recorded by Mrs. Jones (8) are, as she suggests, doubtless to be explained by the fact that her material had been stored in alcohol. These measurements agree with those recorded by Saccardo for *S. libertiana,* (i.e., *S. sclerotiorum*).

This stem rot continues to be an important disease of sunflowers in Manitoba. It is especially common upon sunflowers planted in gardens, or in areas which at some previous time had grown vegetables, since the same fungus is very prevalent on many vegetables (3, 2). On the Agricultural College plots, where sunflowers have followed cereals, the disease has been almost entirely absent. Once this fungus becomes established in the soil, however, it remains there for some time, and crop rotation should be practised. We found that after one year without sunflowers (during which cereals had been grown on the soil), the fungus was still present and produced stem rot upon sunflowers planted the second year. The farmer in Western Canada can greatly lessen the danger of loss from this disease by planting his sunflowers upon fields which have grown grain crops, for the fungus does not attack grains or grasses.

During the summer of 1922, which was rather moist and warm at Winnipeg, sclerotia developed upon alfalfa, soy beans and red clover. I was not in Winnipeg that summer,

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PLATE I.

Figure 1. Two stages of the germination of sclerotia of *S. sclerotiorum* from sunflowers. Enlarged.

Figure 2. The small sclerotia are those obtained from alfalfa seed; the larger ones to the right were in soy-been seed.

Figure 3. Above, sclerotia and seeds of red clover; below, the large irregular sclerotia obtained upon potato plug cultures of the sclerotia shown above. The cultures from sunflower, alfalfa, soy-bean, etc., all produced sclerotia similar to the ones shown below.

Figure 4. Sketch to show one method of fusion between hyphae from two different cultures. The arrows indicate the direction of growth of the hyphae. They appear often to be mutually attracted at points where the hyphae approach each other.

and did not see the affected plants. There was not, however, a conspicuous injury noted upon them, yet when they were threshed sclerotia became separated out from the plants and were found with the seeds. The sclerotia from alfalfa and red clover were small and oval or roundish; those from soy-bean were larger (Plate 1, Figs 2, 3). These sizes were of course partially accounted for by the fact that only sclerotia similar in size to the respective seeds would get through the separator with the grain. It is obvious that these sclerotia might easily be disseminated with such seeds. A search upon the old alfalfa plants in the field in the late autumn of 1922 revealed an occasional sclerotium in the stems. The elongated shape of the sclerotia from alfalfa and soy-bean evidently resulted from their growth within the stems of these hosts. In culture the sclerotia from each host produced mycelium, and sclerotia of irregular size, identical in appearance to those in cultures of the fungus isloated from sunflowers. Reinking (12) reports a Sclerotinia to be serious on Soy-beans in the Philippines.

The Sclerotinia of clover and alfalfa is usually referred to as *S. trifoliorum* Erik. (6, 17). Eastham (4) has reported this disease from British Columbia. Stewart, French and Wilson (13), however, reported *S. libertiana* to cause a wilt of alfalfa. Many consider that these two names refer to the same species of fungus. Wolf and Cromwell (17) consider that there is a morphologic difference between the two, although they did not find any marked difference in pathogenicity: both species, as they considered them, infected both lettuce and crimson clover.

I succeeded early in 1923 in obtaining apothecia from the sclerotia from alfalfa. These bore asci 120-140 by 7½ - 10μ, and spores 10 - 15 by 5½ - 6½μ. These measurements also agree well with those of *S. sclerotiorum*. Wolf and Cromwell record that *S. trifoliorum* has larger asci and spores, but smaller hyphae and sclerotia, than has *S. sclerotiorum*. I found no difference in size or appearance of mycelium or sclerotia in cultures from the various sources. Small microconidia, or "gonidia", are commonly produced by all the cultures I have examined.

Since the affected legumes were grown adjacent to the sunflower field which had been affected by the Sclerotinia, and since the cultures were similiar, I suspected that one and the same fungus was present. I endeavored to prove this in two ways: first by tests of the fusions of hyphae in cultures, and second by cross inoculation tests.

Fusion between hyphae is a common vegetative phenomenon in the fungi. Matsumoto (10) used this as one criterion of the similarity of "strains" of Rhizoctonia. It is evident that if the hyphae from the fungus from alfalfa would fuse with the hyphae from the fungus from sunflower, the fungi must be similar if not really identical. Hanging drops in Van Tieghem cells were inoculated at about 2mm. apart with bits of mycelium from two different sources, and as the hyphae grew into contact, they were watched under the microscope for fusions. As a result of these tests, I found that:—
The hyphae from—

Alfalfa	fused	with	those	from	sunflower
Red Clover	"	"	"	"	soy-bean
Soy-bean	"	"	"	"	sow thistle
Sunflower	"	"	"	"	soy-bean
Parsnip	"	"	"	"	alfalfa

This indicated that the isolations from alfalfa, sunflower, red clover, soy-bean, sow thistle, and parsnip were all the same fungus. Since the one from alfalfa appeared to be *S. sclerotiorum*, evidently they all were. Subsequently the sunflower form also proved to produce apothecia characteristic of *S. sclerotiorum*.

Cross inoculations were first made in the laboratory. The cultures isolated from sunflower and from alfalfa both rotted parsnips, those from soy-bean, red clover, alfalfa and sunflower each rotted carrots. In the field a slight rot of soy-beans was obtained from the fungus from sunflower, and typical rot of sunflower from the culture from soy-bean. Inoculations were ineffective in many cases, perhaps because of the dry weather prevailing in 1923. It may be noted here that no injury was found in 1923 in the same clover and alfalfa fields which had been affected in 1922.

It appears evident that *Sclerotinia sclerotiorum* is the fungus that has attacked the various plants in Manitoba. It also causes a considerable loss of carrots and parsnips in storage. It is recorded from a large number of other vegetables, including beans, beets, celery, cabbage, parsley, tomatoes, potatoes (3, 9), lettuce, and several ornamental palnts. *S. trifoliorum* may be a distinct species upon alfalfa and clover (6, 17), but *S. sclerotiorum* also may attack these plants, and it may be possible that *S. trifoliorum* may yet prove to be only a synonym of *S. sclerotiorum*.

While many crops may be attacked by this fungus, it has so far been found causing special injury in Manitoba only upon sunflowers in the field, and upon carrots and parsnips in storage. Climatic conditions here are usually too dry, and often too cool, for the maximum development of this fungus, and I do not believe it will prove to be a serious disease of alfalfa, clover, soy-beans, or of most other plants, except in occasional instances. It has never been found upon potatoes here, although it is recorded from New Brunswick (9). In cases in which the rot of carrots, parsnips or other vegetables in storage has occurred, a thorough cleaning and disinfection of the cellar or bin would prevent the over-summering of the fungus in such storage houses. The occurrence of trouble in a crop from this fungus should be met with a rotation of non-susceptible crops, such as cereals, corn, or such vegetables as are not mentioned herein as susceptible. It was found in Pennsylvania (11) that the fungus virtually disappears from the soil after two years during which non-susceptible crops are grown.

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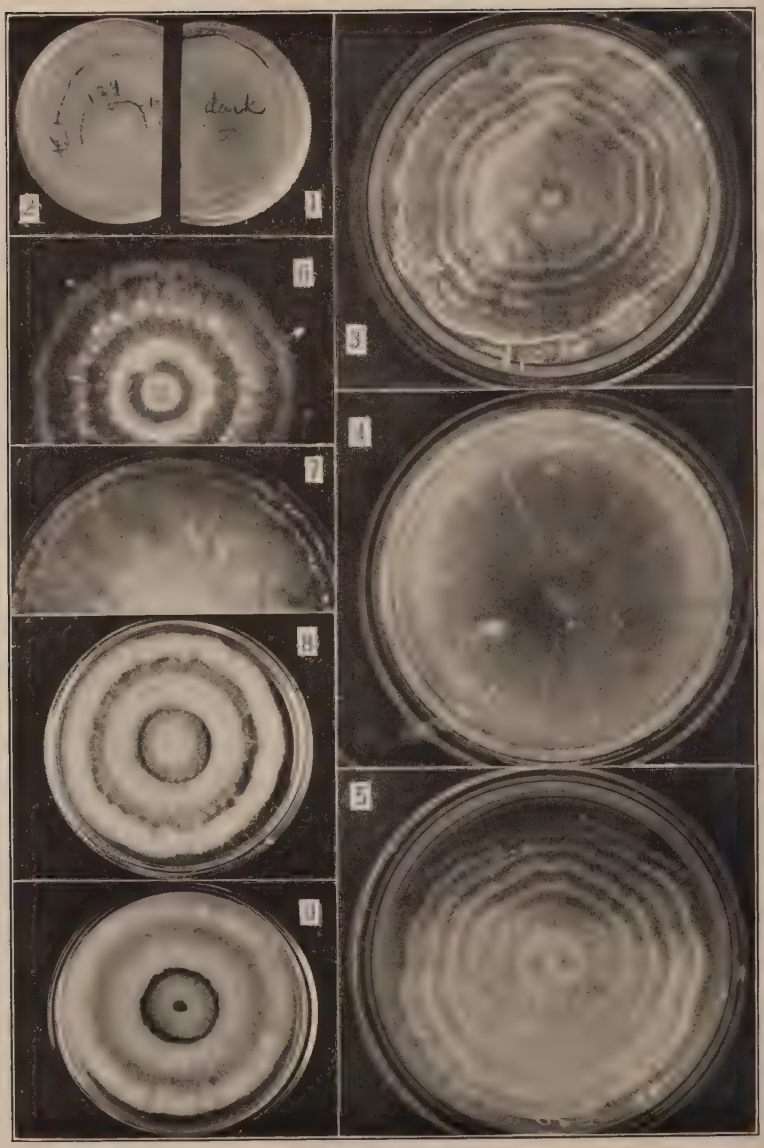

ZONATION IN CULTURES OF FUNGI

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ZONATION IN CULTURES OF FUSARIUM DISCOLOR SULPHUREUM

G. R. Bisby

(With Plate 8)

The effect of light upon plants has received considerable attention of late. Exact quantitative and qualitative measurements have been made of the influence of light in causing phototropic turning of the coleoptiles of oats (see Nienburg, **1919**, Guttenberg, **1919**, Koningsberger, **1923**). The coleoptile appears to respond to a definite intensity of light: Guttenberg finds, for example, that twice as much light is required for the turning, if the coleoptile be shaded along half its longitudinal area, as is required with unshaded coleoptiles. It has long been known that the sporangiophores of *Phycomyces* and of *Pilobolus*, and the fruit bodies of various other fungi, turn toward the light in a manner comparable to the turning of oat coleoptiles. Tollenaar and Blaauw (**1921**) discuss the changing adaptations of sporangiophores of *Phycomyces nitens* to light, their sensitiveness depending upon the amount of light to which they had been exposed before a new light intensity was used. Oltmanns (**1907**) had also noted that the more accustomed the sporangiophores become to light, the higher is the light intensity required for the optimum phototropic response. Blaauw (**1919**) considers that in the cases of phototropic turning of coleoptiles or of sporangiophores in unilateral illumination, the phototropism is a manifestation of a localized growth response to the light; that the phenomenon of phototropism is a secondary phenomenon, the growth reaction being the primary one.

Light is important to many fungi. Miss Westerdijk (**1923**) of the "Centralbureau voor Schimmelcultures" records that fungi in general require light, which may influence fruiting. Leonian (**1924**) found that, of twenty Sphaeropsidales which he grew in culture, no pycnidia were produced in darkness by two species, twelve others showed reduced reproduction in darkness, and only six were unaffected by darkness. The Agaricaceae may also require light: MacDougal (**1903**) found that *Coprinus stercorarius* produced only rudimentary fruit bodies in darkness, but produced normal pilei when light was allowed to act. Brefeld had previously noted similar cases. Buller (**1909**) found that the pilei of *Lentinus lepideus* and of *Polyporus squamosus* were formed as a response to the morphogenic stimulus of light, these fungi being quite sterile in total darkness. Buller also notes that in the rhythmic diurnal development of certain small *Coprini*, light acts as a causal stimulus; but he points out that certain fungi, such as *Psalliota campestris*, develop normally in darkness. *Pilobolus*, according to Buller (**1921**), possesses a pigmented "eye spot" which serves to direct the sporangium toward a source of light.

The formation of zones, *i.e.*, concentric rings, in cultures of fungi on petri dishes, etc., is a very commonly observed phenomenon. It has often been observed that one such ring is formed each day. Hedgcock (**1906**) noted these zones in cultures of *Cephalothecium*, *Penicillium*, *Mucor* and *Hormodendron* exposed to daylight or to blue light during the day. No such zonation was found in cultures grown continuously in the dark, or in red or orange light during the day. Stevens and Hall (**1909**) record that light causes the formation of zones in some fungi, although in others the zones appear to have no reference to illumination. Molz (**1906**) had found that diurnal changes in light conditions cause the formation of concentric zones in cultures of *Sclerotinia fructigena*, the conidial cushions being scattered or absent in darkness. Hutchinson (**1906–7**) also records the formation of concentric zones in *Penicillium* and *Oidium lactis* as a response to light. Milburn (**1904**) had found that concentric zones were produced in cultures of *Hypocrea rufa* in certain media, but were absent in other media, the medium, not light, being the agent

involved in the zone formation. Gallemaerts (**1910**) found that the zones in *Cephalothecium roseum* and other fungi were caused by the alternation of light and darkness, light appearing to hinder the formation of spores. He found that an all-day exposure to red, orange, or blue light, alternating with darkness caused zone formation, but that no zones appeared when the fungi were exposed to continuous light or continuous darkness. He thus differs from Hedgcock as to the effect of red and orange light. Allen and Jolivette (**1914**) state that *Pilobolus* is not strongly phototropic toward yellow light, and still less so toward red light. Miss Parr (**1918**) measured carefully the effect of different portions of the spectrum upon the phototropic response of *Pilobolus*, and found that presentation time decreases gradually from the red to the violet end of the spectrum, the time varying in inverse ratio to the square root of the wave frequency of the light.

EXPERIMENTAL RESULTS

The writer had had *Fusarium discolor sulphureum* in culture for several years. This fungus is a common cause of tuber rot of potatoes in Minnesota (Bisby, **1919**) and in Manitoba. It grows well and produces macroconidia abundantly (so long as the culture is a "high culture") in either light or darkness. Morris and Nutting (**1923**) record that light in general has no appreciable effect upon growth of *Fusaria* except in heightened color in cultures grown in diffuse light.

In working with *Fusarium discolor sulphureum*, at the University of Minnesota in 1918 and 1919, it was found that a moderately short exposure to light suffices to induce the formation of rings of spores. When cultures growing in a dark incubator were removed to the daylight only long enough to mark with a wax pencil the limits of growth, then replaced in the incubator, it was observed that by the following day (or even after about 7 hours) a ring of macroconidia could easily be seen. The ring was formed directly under the pencil mark. No effect was noted on the portions of the culture elsewhere than at the tips of the hyphae. If two exposures were made during one day, two rings were produced. If the cultures were kept in darkness, no rings resulted, yet many conidia were produced irregularly over the

culture. Figs. 1 and 2 show photographs of these cultures taken at Minnesota.

The writer recently made attempts to determine more definitely the amount of light required to produce these rings, since no reference to this point was found in the literature. In an endeavor to determine the amount of daylight required, attempts were first made with camera shutters, but the amount of light reaching the cultures was greatly reduced by the small size of the opening. Finally, the cultures on beef-extract agar with two percent glucose in petri dishes were placed in tight boxes with lids. Then by a little practice with an empty box in which the operation was timed with a watch and compared with the time of opening of the shutter of a camera, it was found that the lid could be opened and closed by hand with an approximation to 1, $\frac{1}{2}$, or $\frac{1}{4}$ second exposure to full daylight of the culture within. The petri dishes were exposed to the diffuse light from a west window in the afternoons. The amount of light of course varied from day to day and, furthermore, passed through a window pane and through the glass of the petri dish. Several trials demonstrated that under the conditions, an exposure of one-fourth to one-half second on a bright day, or one-half to one second on a dull day, resulted in the production of a ring sufficiently well marked to be easily noted by the naked eye (Fig. 3). A longer exposure led to the development of a more conspicuous ring.

Cultures kept in continuous darkness (Fig. 4) or continuous light of uniform intensity, *i.e.*, in a box lighted only by an ordinary electric light bulb of about 25 candle power, showed no rings, although many macroconidia were scattered irregularly over the cultures.

Cultures exposed to the diurnal alternation of daylight and darkness show daily bands of conidia (Fig. 5).

Temperature plays an important part in the phenomenon of zonation. At temperatures below about 18° C., few macroconidia are produced, and, therefore, no zonation can occur. Fig. 7 illustrates a culture exposed to alternate light and darkness at temperatures of 16–18° C. with no zones; the two zones shown at the periphery in the illustration were formed through the influence of light only after the temperature of the culture was raised to about 21° C.

At temperatures of 30° C. or above, a dense uniform growth of conidia (pseudopionnotes) is produced even in darkness (see Bisby, **1919**, p. 23) and exposure to light does not result in the formation of rings.

If a culture wrapped carefully to exclude all light is exposed to alternate high and low temperatures, such as a day in an ice box at about 10° C. followed by a day in an incubator at 25° C., followed by a return to the ice box, etc., zonation is obtained as illustrated in Fig. 6. This, however, is quite a different type of zonation from that resulting from exposure to light, the zones being made up of bands of loose hyphae with few conidia produced at the low temperature, alternating with bands of less fluffy hyphae bearing many irregularly scattered masses of macroconidia formed at high temperatures. Figs. 8 and 9 also illustrate the zonation produced in another *Fusarium* by exposure to alternating high and low temperatures.

In order to obtain more definite figures as to the amount of light required to produce a ring of conidia, use was made of an electric lamp, with a carbon filament standardized to give 25 candlepower. A number of cultures were kept either at room temperature, or were placed in an incubator at about 25° C. The cultures were fixed within boxes in pairs, and each box was wrapped in paper to keep out all light. The boxes were taken into a dark room, unwrapped, and placed at a distance of one meter from the source of light. The light from the 25 candlepower lamp was then turned on. It was found that approximately 6 minutes were required to produce a definite ring.

Since the standardized carbon lamp gave off a somewhat yellowish light, a tungsten-filament lamp, which gave a much whiter light, was tested and found also to be approximately 25 candlepower. When this tungsten lamp was used, it was found that an exposure of 2 to $2\frac{1}{4}$ minutes, at one meter distance, sufficed to produce a ring as sharp as that produced by the light of the carbon lamp for six minutes. An exposure of $2\frac{1}{4}$ minutes represented some 3375 meter candle seconds, a figure that may bear some approximation to from one-half to one second of daylight. Miss Jolivette (**1914**) found that a 16 candlepower tungsten lamp was more effective than a 32 candlepower carbon lamp in causing a reaction in *Pilobolus*.

In order to be sure that the effect was not produced by some factor connected with the handling of the cultures, *e.g.*, a slight change in temperature in removing the boxes from the incubator to the dark room for a few minutes, checks were used in which the boxes were handled in the same way, but with the light off. No zones were produced in petri dishes so treated. Other cultures were kept in continuous darkness: these showed no zonation.

A few tests have been made with other fungi, such as *Cephalothecium roseum*, *Penicillium* spp., *Verticillium alboatrum*, etc. While a similar type of zonation occurred with these fungi as a result of exposure to light, the zones were scarcely as sharp as with *Fusarium discolor sulphureum*. This *Fusarium* also appears to be more sensitive to light than the other fungi used.

It appeared to make no marked difference whether the light reached the culture from above or below, although of course there would be some absorption of light passing through the medium in cases in which the bottom of the petri dish was exposed.

General Discussion

The production of a zone of conidia as a result of exposure to light is a response quite different from that of a phototropic turning of an *Avena* coleoptile or the sporangiophore of *Phycomyces* or of *Philobolus*. The zone comes about as a result of the subsequent formation of conidiophores and conidia at the point where the tips of the spreading hyphae receive the stimulus of light. In darkness, however, conidia are produced, but are scattered over the culture; in other words, *light results in a localization of the production of conidia in the Fusarium*. Although Hedgcock (1906) and Gallemaerts (1910) remark that light inhibits the formation of spores in the fungi with which they worked, Rahn (1912) considers that the greater production of spores by day, and of mycelium by night, accounts for the daily zones of mold colonies. My observations with *F. discolor sulphureum* indicate that fully as many conidia are produced in cultures receiving the short light stimulus as in those remaining in the darkness. It is, of course, true that the conidia are produced in the darkness during a few hours following the short

light exposure. We may perhaps consider that the light gives a brief check to the vegetative growth of the tips of the hyphae, and that the formation of conidiophores follows upon this check.

Fusarium discolor sulphureum develops upon potatoes in dark storage cellars, or in the soil, especially when a partially rotted tuber is planted. The production of conidia at the point where a ray of light strikes the young mycelium may serve as an aid in the dissemination of spores.

Considerably more illumination is required to produce a noticeable zone of conidia in this *Fusarium* than is required to produce a phototropic movement in a coleoptile of oats or in a sporangiophore of *Phycomyces*. The accurate measuring of the effect of different parts of the spectrum, and of precisely the intensity of light required to produce a definite zonation, would require facilities which I have not at the moment available. The production of zones is a response to light that is easily demonstrated, and a permanent record of the result can be kept by preserving the cultures.

I am glad to express my thanks to Dr. A. H. R. Buller for critically reading the manuscript.

SUMMARY

1. Zonation in cultures of *Fusaria* was found to occur from the influence of light or temperature.

2. An exposure of *Fusarium discolor sulphureum* to bright daylight for one-fourth to one-half second is sufficient to produce a ring of conidia which can be detected by the naked eye.

3. A six-minute exposure to the light from a 25 candlepower carbon lamp at one meter distance was required to produce a noticeable ring, but an exposure of 2 to $2\frac{1}{4}$ minutes to a tungsten-filament lamp of about the same candlepower sufficed to induce the zone-formation.

4. The light acts upon the outermost tips of the hyphae, and the phenomenon is, at least in part, another case of the effect of light upon growth.

5. Zonation may also be induced by alternating temperature in constant darkness.

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EXPLANATION OF PLATE 8

Figs. 3, 4, 5, 6 and 7 are from prints made directly by contact with the petri dishes containing the culture. Figs. 1, 2, 8 and 9 are from photographs made at the University of Minnesota.

Fig. 1. *Fusarium discolor sulphureum*, grown in the dark, but exposed to the light and marked before the fungus had covered the plate, with the production of a ring of conidia at the point where the tips of the hyphae were exposed. Above, a little of the mark not erased, covering the ring perfectly.

Fig. 2. A culture kept in the dark in an incubator, except when exposed a moment each day to mark the limits of growth. Some of the marks have been erased. In one case a double ring is formed as a result of two exposures, about five hours apart, in one day.

Fig. 3. Inoculated May 13, 1924. Cultures exposed to daylight by opening the box containing them, before a west window at 2 p. m. each day, as noted below. The cultures were not exposed to sunlight. The fractions of seconds are approximate.

May 15, 5 sec. bright day. Ring produced.
May 16, ¼ sec. bright day. Faint trace of a ring.
May 17, 5 sec. bright day. Well marked ring.
May 18, 1 sec. bright day. Well marked ring.
May 19, 2 sec. bright day. Well marked ring.
May 20, ½ sec. bright day. Slight ring.
May 21, ¼ sec. dull day. No ring.
May 21, removed to full daylight at 5 p. m. Ring produced.

Fig. 4. Inoculated Mar. 31, 1924, kept in the dark continuously until the culture was grown over. No zonation produced. The radii are caused by shrinkage of the medium. Print made June 5.

Fig. 5. Inoculated May 13, 1924. Exposed to alternate day and night in the laboratory. Broad rings mark each day's growth.

Fig. 6. Inoculated July 3, 1924. Kept constantly in the dark. Alternated between an ice box at about 10° C., in which lighter hyphal areas were produced, and an incubator at 25° C., in which darker conidia-bearing areas were formed. The culture was alternated each 24 hours. (Since the print was made directly, the colors are reversed.)

Fig. 7. See explanation in text.

Fig. 8. *Fusarium ?culmorum*. Inoculated Mar. 2, 1919. Kept at about 15° C., for four days; on Mar. 6 the culture was placed out of doors, with the temperature close to freezing, and a bright red zone was produced by mycelium close to or sunken in the medium. Then placed in an incubator at 27°; then in an ice box at 10°, and finally back in the incubator. This fungus produced more mycelium at higher temperatures than at low temperatures, whereas *F. discolor sulphureum* produces spores abundantly at higher temperatures, and mycelium more conspicuously at lower temperatures.

Fig. 9. Reverse (lower) surface of the culture shown from above in Fig. 8

plants from seed of open-fertilized parents, and the strain as a whole to be about 25 per cent. more productive.

Discussion

The results of artificial self-pollination of red clover presented in this paper agree with and supplement the results reported by Fergus (2). During the past two years Fergus has continued to self-pollinate his inbred strains with results* that have confirmed his previous conclusions. The factor or factors which

Table 10—Altaswede Red Clover from Self-fertilized Seed (Family XX—j)

Plant No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Vigor of Growth	S	S	S	S	S	S	S	S	S	S	S	S	M	M
Habit of Growth	M	M	E	E	E	E	M	E	M	M	E	E	M	M
No. of Stalks	O	O	F	N	N	F	O	N	O	O	F	F	O	O
Leafiness	L	L	L	L	L	L	L	L	L	L	L	L	L	L
Size of Leaves	..	..	...	Lg	..	..	..	Lg	Lg	..	Lg	..	..	Sm
Color of Leaves	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG
Leaf Markings	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Pubescence	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Flowers	O	O	O	F	F	F	O	F	O	O	F	F	O	O

For explanation of abbreviations see Table 5.

determine self-fertility have shown marked segregation, and many lines have been lost because a plant apparently lacked the necessary genetical composition for self-fertility. A considerable number of plants have been secured which appear highly self-fertile, and Fergus expects that as the strains become more and more homozygous this character will become homozygous in some of the lines.

The production of self-fertile lines of red clover suggests the possibility of effecting improvement in the crop by the same mode of attack that has been used with maize, i.e., inbreeding for several generations to produce uniform strains and subsequent crossing of those which prove superior. That inbred red clover strains behave in a similar manner to maize is evidenced both by the reduction in vigour of growth and the reduction in variability within each of the strains. The occurrence of chlorophyll deficient seedlings and other abnormalties indicates that strains of red clover may be freed from undesirable recessive characters by self-fertilization.

The desirability of improving the red clover crop with respect to seed production has been widely recognized. This has been especially emphasized by Westgate, Coe and co-workers (10). They discuss the prevalence of infertile ovules as one of the causes of poor seed yields, and express the opinion that this is to a greater or less extent a hereditary character. If red clover strains can be secured which have a high degree of self-fertility, it would seem that an important advance will have been made toward improving the crop with respect to yield of seed. It is also reasonable to assume that similar possibilities exist for improvement of the crop with respect to hardiness, disease resistance and many morphological characters of economic importance.

*Unpublished data.

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Forage Crop Diseases

G. R. BISBY

In a new agricultural area such as Western Canada we find that at first most crops are comparatively free from plant pests, although a few diseases and insects are certain to be brought in with the first lot of seeds that reach a region, and some pass from native wild plants to the new cultivated crop. As time goes on, new diseases appear: Some with seeds that are constantly brought in; others, such as rust, blow in with the winds; others, such as root rot fungi, gradually accumulate in the soil, particularly in the absence of proper crop rotation, and give trouble that was unknown in virgin fields.

A good way to prevent a disease is to keep it out of a region; whether it be human cholera, foot and mouth disease of animals, or flag smut of wheat. The first consideration of the pathologist is to protect the susceptible organism by keeping the germ strictly out of touch with it. Preventive medicine has freed the human race from the fear of many great plagues that formerly swept over countries and decimated the inhabitants; our livestock is also receiving greater protection from disease than once obtained. We have only begun, however, to protect our plants from diseases by endeavoring to keep out the pests by quarantine and inspection, and with the highly developed transportation systems that now span the world there is under any circumstances danger of the crop pest of any part of the world reaching every other part.

Forage crops are still relatively new crops in most areas of the Prairie Provinces. The plant pathologist should stand like a guardian over a crop, and, after having determined what diseases are already present, and having considered possible means of ameliorating these troubles, he should scan the horizon for other pests that are likely to slip in unawares and create more or less havoc. In discussing briefly the diseases of forage crops, I shall first mention, for each crop, the diseases that we have found to occur here. I shall, of course, speak almost entirely of Manitoba, since my observations have been limited to this Province. After considering the possibilities of danger from fungi that are established within our borders, I shall only mention a few which we must anticipate, and one or two which we must endeavor to keep out. Without going too much into technicalities, I hope to give you an idea of the situation in regard to forage crop diseases at present, and to try to guess what the possibilities may be in the future. We have surveyed the forage crops of Manitoa sufficiently to give us a fair idea of the diseases present.

First of all, lest you be alarmed, I can assure that forage crops are, in general, healthy crops. Indeed, I might even go so far as to say that the greater use of forage crops in proper rotations would probably decrease the sum total

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of the losses that plant diseases cause our farmers; too continuous wheat growing, or exclusive grain farming, is certain eventually to result in soil depletion with all the evils and unhealthy conditions which that entails, together with the optimum opportunity for the accumulation of root-rotting soil fungi and certain other plant pests. So long as agriculture remains in the extensive, and not intensive, phase in Western Canada, the control of plant diseases must be sought largely in good agricultural practices, including the use of forage crops in proper rotations.

Alfalfa. The most widespread disease of alfalfa in Manitoba is leaf spot (*Pseudopeziza medicginis*). The loss of some leaves often occurs, particularly after the first cutting. The lower leaves are affected especially on older plants. Leaf spot should sometimes be considered in determining the date of cutting alfalfa for hay, for if the disease is prevalent an earlier cutting will avoid an excessive loss of leaves. We do not, however, look upon leaf spot as serious. A grower in New York reported that dusting alfalfa with sulphur reduced leaf spot, but it is scarcely likely that we shall ever have to resort to any such measure. Michigan reports a variety that is resistant, and as time goes on the production and selection of resistant strains will doubtless gradually reduce the prevalence of this disease.

Root and stem rot (*Sclerotinia sclerotiorum*) was found in alfalfa in 1922. I was afraid that this might prove to be a serious thing, so I carried on a number of experiments with the fungus causing this disease. I have decided that it is not likely to cause much trouble. I found that the fungus was the same one which cause considerable injury to sunflowers. This year I planted alfalfa in soil which had grown a badly diseased crop of sunflowers, but the disease did not appear on the alfalfa. I expect that a little of it may be found in warm and damp summers, on fields infested by the fungus.

Down mildew (*Peronospora trifoliorum*) has been found in a couple of places in Manitoba. I have had it under observation for two or three years, and find that it does not appear to spread much, nor will it kill the plants. The fungus is widespread over North America but seldom serious, and scarcely to be feared under our dry conditions which do not favor such moisture-loving fungi as the downy mildews.

White spot is a minor trouble, occasionally found, about which little is known. The leaves show white areas without chlorophyll. It has been attributed to winter injury to the roots or crown of the plant. Mr. D. B. Shutt obtained evidence that it is associated with the absence of nodule bacteria. We should expect that plants without nodules are likely to be less vigorous, and more susceptible to certain diseases.

I need not discuss dodder here. Although dodder is a parasite, it is usually considered under the category of weeds.

We have collected three other fungus parasites of alfalfa, viz: Yellow leaf blotch (*Pyrenopeziza medicaginis*), stem and leaf spot (*Ascochyta medicaginis*) and another leaf spot (*Pleosphaerulina briosiana*), collected by Mr. I. L. Conners, of Brandon. These are all minor troubles, not likely to become serious here.

I have mentioned eight parasites of alfalfa which we know to occur in Manitoba, but our observations and experiments indicate that none of these produces a really serious or threatening disease. There are eight or ten other fungi known to occur upon alfalfa in other parts of North America, but most of these also are of minor importance. There is one trouble, however, that I hope may be kept out of Western Canada, and that is the eelworm disease (*Tylenchus dipsaci*). In 1922 it was found in Oregon; in 1923 further surveys located it in the Yakima Valley in Washington, in California and in Colorado. We should endeavor to keep this serious pest out, and to eradicate it promptly if it should be found. I believe that the quarantine now in force against the alfalfa weevil might be broadened to include the eelworm disease. Unfortunately, however, this pest attacks various other crops besides alfalfa.

Red Clover. We did not notice powdery mildew of clover (*Erysiphe polygoni*) previous to 1922. A sudden flare-up of this disease in the North-eastern States in 1921 was followed in 1922 by its unprecedented prevalence east of the 100th meridian in North America, and in both 1922 and 1923 it was abundant, and caused some injury at least in Eastern Manitoba. In 1924 it was not so

abundant. The causes for this sudden dissemination of powdery mildew are somewhat obscure. There is, however, a marked difference in susceptibility between strains of red clover, and Professor Southworth will be able, if necessary, to select resistant strains, and has, I believe, already made progress in that direction. I should not be surprised, however, to find that this disease will wane, and in any case it is by no means a prohibitive factor in clover growing.

Rust (*Uromyces trifolii*) was also first found in 1922. I feel sure that it could not have been very abundant around Winnipeg in 1920 or 1921, for I looked for it. It would appear that we may have seen the appearance of two fungi on red clover, and at any rate their occurrence demonstrates that we may expect to find almost any pest of North America appearing, sometimes suddenly, upon our plants. Rust is, however, not looked upon as a very serious disease.

Mosaic (cause unknown) is fairly common upon red clover, and causes some loss of vigor. There are mosaic diseases of many agricultural plants, and their control is difficult, especially since the average grower does not even recognize that there is anything the matter with his plants. I think the time will come when selections will be made to eliminate mosaic, but at the present state of our knowledge regarding transmission between different kinds of plants, its cause, and its seriousness on such crops as clover, it is difficult to make definite suggestions. Mosaic of clover is not to be considered at the moment as a very serious trouble.

The root rot (*Sclerotinia sclerotiorum*) mentioned under alfalfa, has been found also on red clover, but according to tests I have made it appears not to be important.

There are a number of diseases of red clover found elsewhere in addition to these I have mentioned as occurring in Manitoba, but most of them are not especially to be feared.

White Clover has a rust (*Uromyces trifolii-repentis*) and leaf spot (*Polythrincium trifolii*), but these are of minor importance.

Alsike Clover has the same two diseases, although the rust (*Uromyces hybridi*) appears to be distinct.

Sweet Clover is as healthy, in general, as a weed. That is in its favor. The leaf and stem spot (*Ascochyta meliloti*) causes conspicuous blackening of old stems late in the season. Mosaic is frequently found, but causes no especial injury. We found some root rot (*Fusarium sp.*) in the plots this year, which I attribute to an accumulation of the organism in a soil which had grown legumes for some time. We have not as yet found the sclerotial disease which Dr. Newton finds associated with his plants in Alberta.

Soy Bean. Bacterial leaf spot (*Bacterium sp.*) is common but not serious. Mosaic is occasionally found. A root rot (*Fusarium sp.*) similar to the one on sweet clover, killed a few plants in a plot where soy beans were grown the second successive year.

Field Peas may have leaf spots and powdery mildew, but these are minor troubles. I have noticed no fungus disease of the **Vetches.**

We may summarize the diseases of leguminous forage crops which I have enumerated by noting that although we have a number of them with us, and more to be expected, yet they are, on the whole, not especially troublesome, nor is it to be considered that any one of them will assume the ubiquitous destructiveness of a disease such as wheat rust. The farmer who grows these legumes has only to inoculate the seed with nodule bacteria, and for two or three years he need exercise no especial care nor treatment beyond removing possible patches of dodder, and perhaps considering the presence of leaf spot or mildew in relation to dates of cutting. It is certain, however, that the grower should take plant diseases into consideration in all his crops, and sometimes the decision as to whether to cut a crop for hay or to leave it for seed will depend upon the health and vigor of the plants; and with legumes also it is necessary to practice a rotation, and not leave a field for too many years to accumulate senility and disease above ground and below. I look forward to the time when more growers will critically examine their fields now and then, and send in specimens of the diseases they find.

For the plant breeder and plant pathologist there is opportunity to make selections or crosses to provide resistance to certain diseases, and, of course, to provide winter hardiness. This work is being carried on. I have not considered it my province to discuss the killing of plants by frost. Other possible control measures for these diseases must, however, be considered as time goes on.

Grasses

Brome Grass has a conspicuous leaf spot (*Septoria*), which causes some injury to the foliage. Crop rotation may reduce this, and possible resistant strains may be obtainable sometime. The use of seed from fields without this trouble would be a precautionary measure. Ergot (*Claviceps purpurea*) is sometimes quite prevalent in brome grass, and might occasionally render advisable the somewhat earlier cutting of the crop for hay before the ergot bodies developed fully.

Timothy is affected by stem rust (*Puccinia graminis phlei-pratensis*) and sometimes suffers injury from it, although it is not nearly so serious on timothy as on wheat, and in fact this rust was rare in 1924. Leaf spot (*Scolecotrichum graminis*), may be prevalent and somewhat injurious. There is a timothy smut in certain of the States; but it has never been found here, and is not, I think, to be feared under our conditions.

Western Rye is sometimes quite badly smutted. Mr. Fraser has found that this smut (*Ustilago agropyri*) can be prevented by formalin treatment. Rusts (*Puccinia graminis and P. Clematidis*) occur on rye grass, but are not generally very serious. Ergot is also found, and the same considerations might apply as mentioned under brome grass.

Meadow Fescue and Red Top are both attacked by stem rust (*Puccinia graminis*), sometimes rather seriously. **Kentucky Blue Grass** also has a rust (*Puccinia epiphylla*) and may sometimes have ergot, and one or two other minor troubles.

Sudan Grass has a conspicuous leaf spot with purplish borders (*Bacillus sorghi and Piricularia grisea*). This trouble is not especially serious, and resistant strains may some day be obtained.

Panicum Millet is sometimes severeley attacked by smut (*Sorosporium syntherismae*) in Manitoba. This can be prevented by ordinary formalin treatment as for grains. The fox-tail millets may also be smutted, although I have not as yet noted this disease in Manitoba. Formalin also controls the latter smut.

Fodder Corn may bear smut (*Ustilago zeae*) which is more conspicuous than injurious. Smut may become quite abundant if the corn is not rotated. Seed treatment is useless. Rust (*Puccinia sorghi*) is coming to be fairly common in the vicinity of Winnipeg, but is not likely to cause any damage.

Oats and Rye, as hay or pasture crops, generally escape severe rust damage, unless sown very late, and other grain diseases have little opportunity to cause damage, except the root-rot troubles which Dr. Bailey has already discussed.

Other Crops

Sunflowers usually bear considerable rust (*Puccinia helianthi-mollis*) which may cause loss of the lower leaves and reduced silage value. Dr. Bailey has also worked with this disease, and finds that control methods are not at present available, although resistant varieties may eventually be obtainable.

The stem rot (*Sclerotinia sclerotiorum*) is a rather serious disease with which I have carried on a number of experiments. The fungus occurs also upon a number of vegetables, and the disease on sunflowers is worse on fields which have at some previous time grown vegetables. Cereals and grasses are not attacked, and I have never found potatoes to be affected here, but I have already mentioned that alfalfa and clover may show a little of the disease when grown in infected soil. Indeed, even such weeds as sow thistle, Canada thistle and marsh elder may be killed in soils heavily infected with the fungus. Once in the soil, it will persist there over one season without the presence of a susceptible crop, but not indefinitely. This year a number of sunflower plants in the field husbandry plots, following grains, showed the unusual phenomenon of rot of some upper parts of the stem, and not of the root or crown of the plant;

this was evidently due to the lodging of spores, carried by the air, upon these plants. Control can largely be achieved by growing the sunflowers on grain land, at some little distance from the farm yard, and by avoiding the repetition of sunflowers on the same land for a few years.

Leaf spot (*Septoria helianthi*) and mildew (*Erysiphe cichoracearum*) are minor troubles of sunflowers.

Winter Forage Crops, such as mangolds and turnips, have not been found to suffer much from disease with us, although there may be a certain amount of rotting in storage.

There are one or two final considerations with respect to forage crops that have a plant pathologic bearing. First there is the residual effect, or the effect of a crop on the ones which follow. McRostie mentions that poor crops are apt to follow timothy. A growth of a legume, on the other hand, ordinarily is followed by better crops, especially when some of the legume is plowed down. Potato scab is frequently lessened by planting the potatoes after a cover crop plowed down. One residual effect that a forage crop can be expected to show is a greater or lesser diminution in the soil fungi parasitic upon a grain or other different crop.

Secondly might be mentioned the poisoning of stock from moldy legumes. Saprophytic fungi growing upon improperly cured legume hay appear to split the plant proteins into forms which may be so toxic as to cause the death of animals fed with such hay or silage. Proper curing of hay is important, and silage should always be prepared so that molds will not grow through it; in other words the silage must be ground fine, moistened, and packed so as to keep out the air and allow the greater part of the fermentation to be of an anaerobic nature.

The growing of healthy forage crops is aided by proper cultural methods, including the keeping down of weeds, good seed bed preparation, good cultivation, etc., and occasionally by such crop sanitation measures as the destruction of diseased material that may harbor fungi, or carry them over winter. Proper crop rotation is always important, and forage crops should, of course, not be grown successively or, in the case of perennials, indefinitely upon the same land. Seed selection is an aid in obtaining vigorous, healthy plants, and seed treatment is necessary to control millet and rye grass smuts. Legumes should, of course, be inoculated with the proper bacteria before planting. A seed plot may be made of great value in obtaining healthy seed, or in the selection of strains resistant to certain diseases. The plant breeder has still a fertile field before him in the selection and breeding of forage crops resistant to certain diseases.

In spite of all these enumerations and discussions of forage crop diseases, you will understand that most of them, like human colds, are not serious, though they may affect the efficiency of the plant. Rather, we may look upon the increased use of forage crop as an agricultural practice that will lessen the toll of plant diseases, and many of our plant diseases must be lessened by agricultural practices; forage crops conserve soil fertility, allow the best rotations, and are highly desirable from the standpoint of lessening the sum total of plant disease losses.

Barleys for Malting

C. D. McFARLAND

A good malt should be well grown, but not overgrown, and with an even length of acrospire; plump, of good color and pleasant odor, and with a good husk and mealy, friable body, so as to be easily crushed without grinding the husk, containing sufficient diastase to convert the starch body at mashing heats and produce a high extract. The skill of the maltster is directed to produce these results, but without a good malting barley of an even quality and properly matured he can only succeed to a limited extent.

Any seed can be malted, but it is only in malted barley that we can find the important albuminoids and enzymes in proper proportion. There are many

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APPENDIX II

THE PARASITIC FUNGI FOUND IN MANITOBA

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This list includes the fungi and bacteria found to be parasitic upon wild and cultivated hosts in Manitoba, and serves as a summary of our plant disease survey activities during the past five years.

The report of a parasite is represented by one or more herbarium specimens in practically every case. In some instances, portions of the specimens have been submitted to specialists for determination: Dr. John Dearness and Dr. J. J. Davis deserve special mention because of their assistance with difficult identifications. The records are considered to be accurate except in those few instances in which question marks are appended to indicate uncertainty; these marks are placed before names that are in some doubt; when placed after the name of a fungus, uncertainty regarding its parasitism is indicated.

A very few records are from Kenora or Minaki, Ontario, only: these are specified. Cultivated plants are indicated by the abbreviation "cult." or by the use of the common name.

This list of 520 records upon 281 hosts includes 14 bacteria, 21 Phycomycetes, 43 Ascomycetes, 143 Fungi Imperfecti, 25 smuts, 104 rusts, and 6 other Basidiomycetes, a total of 356 species of parasites.

The names of wild host plants have been taken from Rydberg or Britton and Brown, as used by Jackson, Higham & Groh in their check list of Manitoba Flora. The names of cultivated plants are principally as given in Bailey's "Manual of Cultivated Plants."

1. Parasites of vascular plants. (See parasites of fungi and insects below).

Abies balsamea (L.) Mill.
Melampsorella elatina (A. et S.) Schw.
Acer Negundo L.
Lentinus lepideus Fr.
Phyllosticta Negundinis Sacc. et Speg.
Pleurotus ulmarius Fr.
Septoria Negundinis Ell. et Ev.
Acer spicatum Lam.
Phyllosticta minima (B. et C.) Ell. et Ev. (Minaki)
Rhytisma punctatum (Pers.) Fr. (Minaki)
Uncinula circinata Cke. & Pk.
Actaea alba (L.) Mill.
Puccinia Clematidis (D.C.) Lag.
Actaea rubra (Ait.) Willd.
Puccinia Clematidis (DC.) Lag.
Ramularia Actaeae Ell. et Hol.
Agastache anethiodora (Nutt.) Britt.
Sphaerotheca Humuli fuliginea (Schl.) Salm.
Agropyron caninum (L.) R. et S.
Claviceps purpurea (Fr.) Tul.
Puccinia graminis Pers.
Agropyron cristatum (cult.)
Claviceps purpurea (Fr.) Tul.
Puccinia graminis Pers.
Agropyron repens (L.) Beauv.
Claviceps purpurea (Fr.) Tul.
Puccinia graminis Pers.
Agropyron Richardsonii Schrad.
Claviceps purpurea (Fr. Tul.)
Puccinia graminis Pers.
Agropyron Smithii Rydb.
Ascochyta graminicola Sacc.
Claviceps purpurea (Fr.) Tul.
Puccinia graminis Pers.
Puccinia montanensis E. et E.
Agropyron tenerum Vasey
Claviceps purpurea (Fr.) Tul.
Puccinia Clematidis (D.C.) Lag.
Puccinia graminis Pers.
Ustilago Agropyri Clint. in litt.
Agrostis alba L.
Erysiphe graminis DC.
Agrostis stolonifera L.
Erysiphe graminis DC.
Alisma subcordata Raf.
Cladochytrium Alismatis Buesg.
Rhynchosporium Alismatis (Oud.) Davis
Allium Cepa L (Cult.)
Botrytis Allii Munn
Urocystis Cepulae Frost
Alnus incana (L.) Moench
Septoria alnifolia E. et E.
Alopecurus aristulatus Michx.
Uromyces Alopecuri Seym.
Alopecurus pratensis L
Puccinia graminis Pers.
Althaea rosea Cav. (Hollyhock)
Cercospora althaeina Sacc.
Septoria malvicola E. et M.
Amaranthus retroflexus L.
Albugo Bliti (Biv.) Kze.
Alternaria? Solani (E. et M.) J. et G.

Ambrosia trifida L.
Entyloma Compositarum Farl.
Erysiphe Cichoracearum DC.
Puccinia Xanthii Schw.
Ambrosia sp.
Plasmopara Halstedii (Farl.) Berl. et De T.
Amelanchier alnifolia Nutt.
Dimerosporium Collinsii (Schw.) Thüm.
Gymnosporangium ? juvenescens Kern
Gymnosporangium ? clavariaeforme (Jacq.) DC.
Amorpha canescens Pursh,
Uropyxis Amorphae (M.A. Curt.) Schroet.
Andropogon furcatus Muhl.
Puccinia Ellisiana Thuem.
Sphacelotheca occidentalis (Seym.) Clint.
Anemone canadensis L.
Puccinia Clematidis (DC.) Lag.
Antirrhinum majus L. (cult.)
Puccinia Antirrhini D. et H.
Apium graveolens L. (Celery)
Bacillus carotovorus Jones
Septoria Petroselini Apii Br. et Cav.
Apocynum androsaemifolium L.
Cercosporella Apocyni (E. et K.) Trel.
Arabis sp.
Puccinia monoica Peck.
Aralia nudicaulis L.
Nyssopsora clavellosa (Berk.) Arth.
Arctium minus Schk.
Puccinia Bardanae Corda
Argentinia Anserina (L.) Rydb.
Ramularia arvensis Sacc.
Artemisia gnaphalodes Nutt.
Cylindrosporium Artemisiae D. et Barth.
Puccinia Absinthii DC.
Puccinia universalis Arth.
Asclepias sp.
Colletotrichum fusarioides (Ell. et Kell.) O'Gara
Asparagus officinalis L. (cult.)
Puccinia Asparagi DC.
Aster laevis L.
Coleosporium Solidaginis (Schw.) Thüm.
Aster Lindleyanus T. et G.
Erysiphe Cichoracearum DC.
Aster novae-angliae L.
Puccinia Asteris Duby
Aster spp.
Coleosporium Solidaginis (Schw.) Thüm.
Puccinia Asterum (Schw.) Kern.
Avena fatua L.
Puccinia graminis Pers.
Avena sativa L. (cult.)
Helminthosporium Avenae Eidam
Leptosphaeria avenaria Weber
Puccinia graminis Pers
Puccinia Rhamni (P. coronata Cda.)
Ustilago Avenae (Pers.) Jens.
Ustilago levis (K. et S.) Magn.
Beckmannia erucaeformis (L.) Host.
Puccinia graminis Pers.
Puccinia Rhamni (Pers.) Wettst.
Ustilago striaeformis (West.) Niessl.
Berberis vulgaris L. (cult.)
Puccinia graminis Pers.
Beta vulgaris L. (cult.)
Phoma Betae Fr.
Betula spp.
Polyporus betulinus Bull.
Bidens frondosa L.
Septocylindrium concomitans (E. & H.) Hals.
Brassica oleracea var. botrytis L. (Cauliflower)
Bacillus carotovorus Jones
Brassica oleracea var, capitata L. (Cabbage)
Bacillus carotovorus Jones.
Brassica sp.
Albugo candida (Pers.) Kze.
Briza maxima L
Puccinia graminis Pers.
Bromus ciliatus L.
Puccinia Clematidis (DC.) Lag.
Puccinia Rhamni (Pers.) Wettst.
Bromus inermis Leyss (Cult.)
Claviceps purpurea (Fr.) Tul.
Septoria Bromi Sacc.
Septoria bromigena Sacc.
Bromus latiglumis (Shear) Hitch.
Puccinia Clematidis (DC.) Lag.
Bursa Bursa-pastoris (L.) Britton
Peronospora parasitica (Pers.) Tul.
Calamagrostis canadensis (Michx.) Beauv.
Claviceps purpurea (Fr.) Tul
Puccinia Rhamni (Pers.) Wettst.
Calamovilfa longifolia (Hook.) Hack.
Puccinia amphigena Dietel
Callistephus chinensis Nees. (cult. Aster)
Coleosporium Solidaginis (Schw.) Thüm.
Fusarium conglutinans Callistephi Beach
Septoria Callistephi Gloyer
Caltha palustris L.
Puccinia calthaecola Schr.
Carex Douglasii Boot.
Puccinia universalis Arth.
Carex durifolia Bailey
Puccinia eminens Kern
Carex praegracilis W. Boott.
Puccinia universalis Arth.
Carex Sartwelli Dewey
Puccinia Peckii (De T.) Kell.
Carex scoparia Schk.
Puccinia Asterum (Schw.) Kern
Carex varia Muhl.
Cintractia Caricis (Pers.) Magn.
Carex vesicaria L.
Phyllosticta Caricis (Fckl.) Sacc.
Septoria Caricis Pass.
Stagonospora ? albescens Davis
Carex spp.
Puccinia Grossulariae (Schum.) Lagerh.
P. hieraciata (Schw.) Jackson
P. urticata (Link) Kern
Celastrus scandens L.
Ramularia Celastri E. et M.
Cerastium arvense L.
Melampsorella elatina (A. et S.) Schw.
Chaetochloa glauca (L) Scribn.
Ustilago neglecta Niessl.
Chaetochloa sp.
Piricularia ? grisea (Cke.) Sacc.
Sclerospora graminicola (Sacc.) Schroet.
Chamaesyce sp.
Uromyces proeminens (DC.) Pass.
Chamaenerion angustifolium Scop.
Puccinia gigantea P. Karst
Puccini Castrum Abieti-chamaenerii Kleb.
Pucciniastrum Abieti-Chamaenerii Kleb.
Ramularia punctiformis (Schl.) Hoehn.
Cheirinia cheiranthoides (D.) Link
Peronospora parasitica (Pers.) Tul.
Chrysanthemum sp. (cult.)
Oidium Chrysanthemi Rab.
Cicuta maculata L.
Puccinia Cicutae Thuem.

Cirsium arvense (L.) Scop.
Albugo Tragopogonis (DC.) S.F.G.
Pyrenochaeta ? erysiphoides Sacc.
Sclerotinia sclerotiorum (Lib.) Massee
Cirsium Flodmanii (Rydb.) Arth.
Puccinia Cirsii Lasch.
Clematis sp.
Cylindrosporium Clematidis E. et E.
Comandra pallida A. DC.
Cronartium Comandrae Peck.
Puccinia Androgogonis Schw.
Convolvulus sepium L.
Puccinia Convolvuli (Pers.) Cast.
Septoria Convolvuli Desm.
Cornus stolonifera Michx.
? Phyllactinia corylea (Pers.) Karst.
Septoria cornicola Desm.
Corylus americana Walt.
Gnomoniella Coryli (Batsch) Sacc.
Septoria corylina Peck
Crataegus spp.
Gymnosporangium ? germinale (Schw.) Kern
Phyllosticta Crataegi (Cooke) Sacc.
Cucumis sativus L. (cult.)
Bacterium lacrymans Sm. et Bryan
Bacillus tracheiphilus E. F. S.
Cladosporium cucumerinum E. et A.
Dactylis glomerata L.
Claviceps purpurea (Fr.) Tul.
Puccinia graminis Pers.
Dasystephana Andrewsii (Griseb.) Small
Asteroma Gentianae Fckl.
Daucus Carota var. sativa DC. (cult.)
Sclerotinia sclerotiorum (Lib.) Massee
Delphinium (cult.)
Erysiphe Polygoni DC.
Diervilla Diervilla (L.) MacMill.
Septoria ? diervillicola E. et E. (Minaki)
Distichlis stricta (Torr.) Rydb.
Puccinia subnitens Diet.
Doellingeria umbellata (Mill.) Nees.
Coleosporium Solidaginis (Schw.) Thuem.
Eleagnus argentea Pursh.
Aecidium Allenii Clint.
Eleocharis sp.
Puccinia Eleocharidis Arth.
Elymus canadensis L.
Claviceps purpurea (Fr.) Tul.
Phyllachora graminis (Pers.) Fckl.
Puccinia Clematidis (DC.) Lagerh.
Puccinia graminis Pers.
Puccinia montanensis Ellis.
Elymus innovatus Beal
Claviceps purpurea (Fr.) Tul
Elymus Macounii Vasey
Claviceps purpurea (Fr.) Tul.
Puccinia Clematidis (DC.) Lagerh.
Puccinia graminis Pers.
Elymus virginicus L.
Phyllachora graminis (Pers.) Fckl.
Elymus sp.
Urocystis Agropyri (Preuss.) Schr.
Epilobium adenocaulon Haussk.
Puccinia strum Epilobii (DC.) Otth.
Eupatorium purpureum L.
Puccinia Eleccharidis Arth.
Falcata comosa (L.) Kuntze
Woroniella aecidioides (Peck) Syd.
Festuca elatior L.
Puccinia graminis Pers.

Fragaria spp. (cult. and wild)
Botrytis ? cinerea Pers.
Ramularia Tulasnei Sacc.
Rhizopus nigricans Ehr.
Fraxinus pennsylvanica Marsh
Fomes igniarius Fr.
Hysterographium Fraxini (Pers.) De Not.(?)
Phyllosticta viridis E. et K.
Piggotia Fraxini B. et C.
Septoria Besseyi Pk.
Galium boreale L.
Puccinia rubefaciens Johans.
Glycyrrhiza lepidota Nutt.
Uromyces Glycyrrhizae (Rab.) P. Magn.
Grindelia squarrosa (Pursh) Dunal
Puccinia Asterum (Schw.) Kern
Hedysarum boreale Nutt.
Uromyces Hedysari-obscuri (DC.) Carest. et Picc.
Helenium autumnale L.
Septoria Helenii E. et E.
Helianthus annuus L. (cult.)
Erysiphe Cichoracearum DC.
Puccinia Helianthi-mollis (Schw.) Jackson
Sclerotinia sclerotiorum (Lib.) Massee
Septoria Helianthi E. et K.
Helianthus petiolaris, Nutt.
Septoria Helianthi E. et K.
Helianthus tuberosus L.
Sclerotinia sclerotiorum (Lib.) Massee
Heracleum lanatum Michx.
Phyllosticta Heraclei E. et D.
Ramularia Heraclei (Oud.) Sacc.
Hieracium canadense Michx.
Puccinia hieraciata (Schw.) Jackson
Holcus Sorghum sudanensis Hitchc. (cult.)
Bacillus Sorghi Burr.
Piricularia ? grisea (Cke.) Sacc.
Hordeum jubatum L.
Erysiphe graminis DC.
Puccinia Clematidis (DC.) Lagerh.
Puccinia graminis Pers.
Ustilago Lorentziana Thuem.
Hordeum vulgare L. (cult.)
Bacterium translucens J. J. et R.
Claviceps purpurea (Fr.) Tul.
Erysiphe graminis DC.
Helminthosporium gramineum Rab.
Helminthosporium sativum P. K. et B.
Helminthosporium teres Sacc.
Puccinia anomala Rostr.
Puccinia graminis Pers.
Septoria Passerinii Sacc.
Ustilago Hordei (Pers.) K. et S.
Ustilago nuda (Jens.) K. et S.
Humulus lupulus L.
Phyllosticta Humuli Sacc. et Speg.
Impatiens spp.
Plasmopara obducens Schr.
Puccinia Impatientis (Schw.) Arth.
Iris sp. (cult.)
Heterosporium gracile (Wal.) Sacc.
Iva xanthifolia Nutt.
Basidiophora Kellermanii (E. et H.) Wilson
Sclerotinia sclerotiorum (Lib.) Massee
Septoria ivaecola E. et E.
Juncus balticus Willd.
Uromyces Junci (Desm.) Tul.
Juncus filiformis L.
Uromyces Junci (Desm.) Tul.

Juniperus sibirica Burgsd.
Gymnosporangium germinale (Schw.) Kern
Lactuca pulchella (Pursh) D.C.
Bremia Lactucae Regel
Puccinia hemisphaerica (Peck.) E. et E.
Lactuca sativa L. (cult.)
Alternaria sp.
Botrytis cinerea Pers.
Puccinia hieraciata (Schw.) Jackson
Sclerotinia sclerotiorum (Lib.) Massee
Lathyrus ochroleucus Hook.
Uromyces Fabae (Pers.) de Bary
Lathyrus odoratus L. (cult.)
Microsphaera ? diffusa Cke. et Peck
Rhizoctonia Solani Kuehn.
Lathyrus venosus Muhl.
Cercospora Lathyri D. et H.
Septoria Astragali Rob.
Ledum groenlandicum Oeder
Melampsoropsis ledicola (Peck) Arth.
Leontodon Taraxacum L.
Puccinia Taraxaci (*P. Hieracii* (Schum.) Mart.)
Ramularia Taraxaci Karst.
Sphaerotheca Humuli fuliginea (Schl.) Salm.
Lepargyraea argentea (Nutt.) Greene
Cercospora manitobana Davis
Lepargyraea canadensis (L.) Greene
Aecidium Allenii Clinton
Lepidium densiflorum Schrad.
Peronospora parasitica (Pers.) Tul.
Linum Lewisii Pursh
Melampsora Lini (Schum.) Desm.
Linum usitatissimum L. (cult.)
Fusarium Lini Bolley
Melampsora Lini (Schum.) Desm.
Lonicera glaucescens Rydb.
Cercospora antipus E. et H.
Lonicera spp.
Microsphaera Alni (Wall.) Salm.
Lychnis chalcedonica L. (cult.)
Septoria Melandrii Pass.
Lycopersicum esculentum L. (cult.)
Alternaria Solani (E. et M.) J. et G.
Cladosporium fulvum Cke.
Septoria Lycopersici Speg.
Lygodesmia juncea (Pursh) D. Don.
Puccinia Grindeliae Peck
Malva rotundifolia L.
Septoria heterochroa Desm.
Malvastrum coccineum (Nutt.) A. Gray
Puccinia Sherardiana Koern.
Matteuccia Struthiopteris (L.) Tod.
Uredinopsis Struthiopteridis Stoerm.
Medicago sativa L. (cult.)
Ascochyta Medicaginis Bres.
Peronospora Trifoliorum de B.
Pleosphaerulina Briosiana Pol.
Pseudopeziza Medicaginis (Lib.) Sacc.
Pyrenopeziza Medicaginis Fckl.
Sclerotinia sclerotiorum (Lib.) Massee
Melilotus alba Desr. (cult.)
Ascochyta Meliloti (Trel.) Davis
Cercospora Davisii Ell. et Ev.
Menispermum canadense
Cercospora Menispermi E. et H.
Entyloma Menispermi Farl. et Trel.
Mentha canadensis L.
Puccinia angustata Peck.
Puccinia Menthae Pers.
Mentha glabrior (Hook.) Rydb.
Puccinia Menthae Pers.
Micrampelis lobata (Michx.) Greene
Septoria Sicyi Peck
Monarda fistulosa L.
Puccinia Menthae Pers
Muhlenbergia mexicana (L.) Trin.
Phyllachora graminis (Pers.) Fckl.
Nabalus albus (L.) Hook.
Puccinia hieraciata (Schw.) Jackson
Septoria ? Nabali B. et C.
Naumburgia thyrsiflora (L.) Duby
Puccinia lysimachiata (Link) Kern.
Nicotiana sp. (Ornamental)
Alternaria sp.
Oenothera biennis L.
Puccinia Peckii (De Toni) Kell.
Septoria Oenotherae West.
Padus virginiana (L.) Mill.
Cylindrosporium lutescens Higgins
Phyllosticta virginiana (E. et H.) Seaver
Podosphaera Oxyacanthae (DC.) de Bary
Paeonia sp. (cult.)
Botrytis Paeoniae Oud.
Panicularia grandis (S. Wats.) Nash
Claviceps purpurea (Fr.) Tul.
Panicum capillare L.
Phyllachora graminis (Pers.) Fckl.
Panicum miliaceum L.
Sorosporium Syntherismae (Peck) Farl.
Parthenocissus quinquefolia (L.) Planch.
Uncinula necator (Schw.) Burr.
Pastinaca sativa L. (cult.)
Sclerotinia sclerotiorum (Lib.) Massee
Pelargonium (cult.)
?Bacillus caulivorus Pril. & Del.
Botrytis cinerea Pers.
Persicaria Hartwrightii (A. Gray) Greene
Puccinia Polygoni-amphibii Pers.
Persicaria Muhlenbergii (Meisn.) Small
Puccinia Polygoni-amphibii Pers.
Phalaris arundinacea L.
Puccinia Majanthae (Schum.) Arth.
Phalaris canariensis L. (cult.)
Puccinia graminis Pers.
Phaseolus vulgaris L. (cult.)
Colletotrichum Lindemuthianum (Sacc. et Magn), Br. et Cav.
Pseudomonas Phaseoli E. F. S.
Phleum pratense L.
Claviceps purpurea (Fr.) Tul.
?Heterosporium Phlei Gregory
Puccinia graminis Pers.
Scolecotrichum graminis Fckl
Phragmites Phragmites (L.) Karst.
Puccinia Magnusianum Koern.
Puccinia rubella (Pers.) Arth.
Ustilago sp.
Physalis heterophylla Nees.
Puccinia Physalidis Pk.
Physalis virginiana Mill.
Puccinia Physalidis Pk.
Picea Abies Karst. (cult.)
Peridermium coloradense (Diet.) Arth. et Kern
Picea Mariana (Mill.) B.S.P.
Melampsoropsis ledicola (Peck) Arth.
Pinus Banksiana Lamb
Coleosporium ? Solidaginis (Schw.) Thuem.
Hypodermella ampla (Davis) Dearn.
Lophodermium Pinastri (Schr.) Chev.
Pisum sativum L. (cult.)
Ascochyta Pisi Lib.
Colletotrichum Pisi Pat.

Pisum sativum L. (cult.)—*con.*
Erysiphe Polygoni DC.
Pseudomonas Pisi Sack.
Septoria flagellifera Ell. & Ev.
Septoria Pisi West.
Uromyces Fabae (Pers.) de Bary
Plantago major L.
Erysiphe Cichoracearum DC.
Septoria Plantaginis Pass.
Poa arida Vasey
Puccinia Clematidis (DC.) Lagerh.
Poa pratensis L.
Claviceps purpurea (Fr.) Tul.
Colletotrichum cereale Manns.
Erysiphe graminis DC.
Puccinia epiphylla Wettst. (*P. Poarum* Niels.)
Sporotrichum Poae Pk.
Polygonum aviculare L.
Cercospora avicularis Wint.
Erysiphe Polygoni DC.
Uromyces Polygoni (Pers.) Fckl.
Populus balsamifera L.
Septoria musiva Pk.
Populus tremuloides Michx.
Cladosporium subsessile Ell. et Barth.
Fomes igniarius Fr.
Napicladium Tremulae (Fcl.) Sacc.
Septoria musiva Pk.
Populus spp.
Cytospora chrysosperma (Pers.) Fr.
Melampsora ? Medusae Thuem.
Uncinula Salicis (DC.) Wint.
Portulaca oleracea L.
Albugo Portulaceae (DC.) Kuntze
Potentilla bipinnatifida Dougl.
Phragmidium Potentillae (Pers.) Karst.
Potentilla glabrella Rydb.
Phragmidium Potentillae (Pers.) Karst.
Potentilla pennsylvanica L.
Phragmidium Potentillae (Pers.) Karst.
Potentilla strigosa Pall.
Phragmidium Potentillae (Pers.) Karst.
Prunus Besseyi Bailey
Sclerotinia cinerea (Bon.) Wor.
Prunus pennsylvanica L. f.
Exoascus Pruni Fckl.
Cylindrosporium hiemale Higg.
Prunus spp. (cult. and wild)
Cephalothecium roseum Cda.
?Cladosporium carpophilum Thuem.
Cylindrosporium hiemale Higg.
Exoascus Pruni Fckl.
Nectria cinnabarina (Tode) Fr. (?)
Plowrightia morbosa (Schw.) Sacc.
Podosphaera Oxyacanthae (DC.) de Bary
Saccharomyces sp.
Sclerotinia cinerea (Bon.) Wor.
Stereum purpureum Pers.
Pulsatilla ludoviciana (Nutt.) Heller
Polythelis Pulsatillae (Rostr.) Arth.
Urocystis Anemones (Pers.) Wint.
Pyrola americana Sweet
Melampsoropsis Pyrolae (DC.) Arth.
Puccinastrum Pyrolae (Pers.) Diet.
Pyrus Malus L. (cult.)
Bacillus amylovorus (Burr.) Trev.
Penicillium spp.
Physalospora Cydoniae Arn.
Venturia inaequalis (Cke) Wint.
Quercus macrocarpa Michx.
Marssonia Martini (Sacc. et Ell.) Magn.
Microsphaera Alni (Wallr.) Wint.
Phyllosticta livida E. & E.
Radicula palustris (L.) Moench.
Albugo candida (Pers.) Kuntze
Ranunculus abortivus L.
?Puccinia Eatoniae Arth.
Ranunculus Macounii Britton
Uromyces Alopecuri Seym.
Ranunculus sceleratus L.
Uromyces Alopecuri Seym.
Raphanus sativus L. (cult.)
Albugo candida (Pers.) Kuntze
Pythium de Baryanum Hesse
Rhamnus alnifolia L'Hér.
Puccinia Rhamni (Pers.) Wettst.
Rhamnus cathartica L. (cult.)
Puccinia coronata Corda
Rheum Rhaponticum L. (Cult.)
Phyllosticta straminella Bres.
Ribes nigrum L. (cult.)
Puccinia Grossulariae (Schum.) Lagerh.
Septoria Ribis Desm.
Ribes odoratum Wendl. (cult.)
Septoria aurea E. et E.
Ribes spp. (cult. and wild)
Puccinia Grossulariae (Schum.) Lagerh.
Septoria Ribis Desm.
? *Sphaerotheca Mors-uvae* (Schw.) B. et C.
Roripa Armoracia Hitchc. (cult.)
Ramularia Armoraciae Fckl.
Rosa acicularis Lindl.
Phragmidium Rosae-acicularis Liro
Rosa blanda Ait., R. spp. (wild)
Cercospora rosaecola Pass.
Earlea speciosa (Fr.) Arth.
Phragmidium montivagum Arth.
Rosa spp. (cult.)
Phragmidium americanum Diet.
Phragmidium disciflorum (Tode) J. F. James
? *Sphaerotheca pannosa* (Wallr.) Lév.
Rubus strigosus Michx.
Didymosphaeria manitobiensis E. et E.
Phragmidium imitans Arth.
Rubus triflorus (R. pubescens Raf.)
Discosia artocreas (Tode) Fr. (?)
Gymnoconia interstitialis (Schl.) Lagerh.
Pucciniastrum arcticum (Lag.) Tranz.
Rubus spp. (cult. & wild)
Coniothyrium Fuckelii Sacc.
Phoma sp. (*Mycosphaerella rubina* (Pk) Jacz.)
Septoria Rubi (*Mycosphaerella Rubi* Roark)
Sphaerotheca Humuli fuliginea (Schl.) Salm.
Rudbeckia laciniata L.
Phyllosticta Rudbeckiae E. et E.
Plasmopara Halstsdii (Farl.) Berl. et de T.
Ramularia Rudbeckiae Pk.
Septoria Rudbeckiae E. & H.
Uromyces Rudbeckiae A. et H.
Rumex crispus L.
Ramularia decipiens E. et E.
Rumex mexicanus Miesn.
Puccinia rubella (Pers.) Arth.
Rumex occidentalis S. Wats.
Puccinia rubella (Pers.) Arth.
Salix spp.
Fomes igniarius Fr.
Melampsora Bigelowii Thuem.

Salix spp.—*con.*
Rhytisma salicinum Fr.
Septoria ? salicina Pk.
Uncinula Salicis (DC.) Winter
Sanicula marylandica L.
Puccinia marylandica Lindl.
Schizachyrium scoparium (Michx.) Nash
Puccinia Andropogonis Schw.
Scirpus microcarpus Presl.
Puccinia angustata Peck.
Scolochloa festucacea (Willd.) Link
Claviceps purpurea (Fr.) Tul.
Puccinia Rhamni (Pers.) Wettst.
Secale cereale L. (cult.)
Claviceps purpurea (Fr.) Tull.
Erysiphe graminis DC.
Puccinia Asperifolii (Pers.) Wetts.
Puccinia graminis Pers.
Urocystis occulata (Wallr.) Rab.
Sium cicutaefolium Gmel.
Fusicladium depressum (B. et Br.) Sacc.
Smilax herbacea L.
Puccinia amphigena Diet.
Stagonospora Smilacis (E. et M.) Sacc.
Vermicularia Liliacearum West.
Soja max Piper (cult.)
Bacterium glycineum Coerper or *B. Sojae* Wolf
Fusarium sp.
Solanum Melongena L. (cult.)
Alternaria sp.
Solanum tuberosum L. (cult.)
Actinomyces scabies (Thaxt.) Güssow
Alternaria Solani (E. et M.) J. et G.
Bacillus atrosepticus v. Hall
Colletotrichum atramentarium (B. et B.) Taub.
Corticium vagum B. et C.
Fusarium coeruleum (Lib.) Sacc.
Fusarium discolor sulphureum (Schl.) A. et W.
Fusarium oxysporum Schl.
Spondylocladium atrovirens Harz
Stysanus stemonitis Corda (?)
Verticillium albo-atrum McA.
Solidago spp.
Coleosporium Solidaginis (Schw.) Thuem.
Puccinia Asterum (Schw.) Kern
Sonchus arvensis L.
Sclerotinia sclerotiorum (Lib.) Massee
Septoria sonchifolia Cke.
Sorbus americana Marsh
Gymnosporangium cornutum (Pers.) Arth.
Spartina cynosuroides (L.) Roth.
Claviceps purpurea (Fr.) Tul.
Spartina Michauxiana Hitchc.
Puccinia Distichlidis E. et E.
Uromyces acuminatus Arth.
Spiraea alba Du Roi
Septoria Salicifoliae (Trel.) E. et E.
Stachys palustris L.
Erysiphe Galeopsidis DC.
Steironema ciliatum (L.) Raf.
Phyllosticta decidua E. et K.
Puccinia Distichlidis E. et E.
Septoria conspicua E. et M.
Stipa comata Trin. et Rup.
Puccinia Stipae Arth.
Stipa viridula Trin.
Puccinia substerilis E. et E.
Ustilago hypodytes (Schl.) Fries
Symphoricarpos spp.
Microsphaera diffusa Cke. et Pk.
Puccinia abundans (Peck) Jackson
Septoria Symphoricarpi E. et E.
Syringa vulgaris L. (Lilac)
Microsphaera Alni (Wallr.) Wint.
Thalictrum dasycarpum Fisch. et All.
Puccinia Clematidis (DC) Lagerh.
Thalictrum venulosum Trel.
Polythelis Thalictri (Chev.) Arth.
Puccinia Clematidis (DC.) Lagerh.
Tiniaria cilinodis (Michx.) Small
Ramularia cilinodis (Minaki)
Tiniaria Convolvulus (L.) Webb et Moq.
Puccinia Polygoni-amphibii Pers.
Septoria Polygonorum Desm.
Ustilago anomala (Kuntze) Wint.
Torresia odorata (L.) Hitchc.
Puccinia graminis Pers.
Toxicodendron radicans (L.) Kuntze
Cercospora rhoina C. et E.
Pileolaria Toxicodendri (B. et R.) Arth.
Trientalis americana Pursh
Septoria increscens Pk. (Minaki)
Trifolium hybridum L. (cult.)
Polythrincium Trifolii Kze.
Uromyces hybridi Davis
Trifolium medium L. (cult.)
Uromyces Trifolii (Hedw.) Lév.
Trifolium pratense L. (cult.)
?Erysiphe Polygoni DC.
Uromyces Trifolii (Hewd.) Lév.
Trifolium repens L. (cult.)
Cercospora zebrina Pass.
Polythrincium Trifolii Kze.
Uromyces Trifolii repentis (Cast.) Liro
Trisetum spicatum (L.) Richter
Puccinia monoica (Peck) Arth.
Triticum spp. (wheat)
Bacterium atrofaciens McCulloch
Bacterium translucens undulosum S. J. et R.
Cladosporium graminum Corda (?)
Claviceps purpurea (Fr.) Tul.
Erysiphe graminis DC.
Fusarium culmorum (W. Sm.) Sacc.
Gibberella Saubinetii (Mont.) Sacc.
Helminthosporium sativum P. K. et B.
Puccinia graminis Pers.
Puccinia triticina Eriks.
Septoria nodorum Berk.
Septoria Tritici Desm.
Tilletia laevis Kuehn
Tilletia Tritici (Bjerk.) Wint.
Ustilago Tritici (Pers.) Jens.
Ulmus americana L.
Gnomonia Ulmea (Schw.) Thuem.
Pleurotus ulmarius Fr. (?)
Unifolium canadense (Desf.) Greene
Puccinia Majanthae (Schum.) A. et H.
Urtica gracilis Ait.
Puccinia urticata (Link) Kern
Ramularia Urticae Ces.
Vaccinium sp.
Calyptospora columnaris (A. et S.) Kuehn (Minaki)
Vagnera stellata (L.) Morong
Phyllosticta Convallariae Pers.
Puccinia Majanthae (Schum.) A. et H.
Uromyces acuminatus Arth.
Viburnum Lentago L.
Microsphaera Alni (Wallr.) Wint.

Viburnum Opulus L.
Cercospora Opuli (Fcl.) v. H.
Vicia americana Muhl.
Peronospora Viciae (Berk.) de Bary
Uromyces Fabae (Pers.) de Bary
Uromyces porosus (Peck) Jackson
Viola tricolor var. hortensis DC. (cult.)
Cercospora Violae-tricoloris Br. et Cav.
Sphaerotheca Humuli fuliginea (Schl.) Salm.
Viola spp.
Puccinia Ellisiana Thuem.
Puccinia Violae (Schum.) DC.
Zea Mays L. (cult.)
Bacillus Sorghi Burr
Puccinia Sorghi Schw.
Ustilago Zeae (Beck.) Ung.
Zizia aurea (L.) Koch
Puccinia Angelicae (Schum) Fckl.

II. Parasites of fungi and insects.

Lactarius piperatus Fr.
Hypomyces lactifluorum (Schw.) Tul.
Lentinus lepideus Fr.
Sporodinia grandis Link (?)
Mushroom
Eleutheromyces subulatus (Tode) Fckl.
Podosphaera Oxyacanthae (DC.) de Bary
Ciccinobolus sp.
Polyporus versicolor (L.) Fr.
Hypomyces aurantius (Pers.) Tul.
Uredineae
Darluca filum (Biv.) Cast.
Valsa sp.
Nectria episphaeria (Tode) Fr.
Aphid (on sunflower)
Empusa Aphidis Hoffm.
Ctenucha virginica (N. sedge Moth)
Entomophthora Grylli
Dissoteira carolina (grasshopper)
Entomophthora Gryli
Melanopus sp. (grasshopper)
Entomophthora Grylli
Musca domestica (house fly)
Empusa Muscae Cohn.

Circular No. 85 January, 1927

MANITOBA DEPARTMENT OF AGRICULTURE AND IMMIGRATION,
WINNIPEG, CANADA.

PREVENTION OF CEREAL SMUTS

to you, pass on to someone else who
may be interested in the subject.

A—A head of Prelude Wheat showing 14 bunt balls. The stinking or covered smut of wheat.
B—The loose smut of wheat. It has destroyed all the kernels.

By G. R. BISBY,
Botany and Biology Department,
Manitoba Agricultural College,
Winnipeg, Manitoba

By Authority of Hon. Albert Prefontaine, Minister of Agriculture and Immigration.

Prevention of Cereal Smuts

HUNDREDS of thousands of bushels of wheat, oats and barley are destroyed in Manitoba fields each year by smuts. Much of this loss might easily be prevented by seed treatment.

Aside from the actual grain destroyed, there is a great loss from smutty grades, and this might also be prevented by seed treatment.

Smut is caused by a fungus which grows up inside the plant and destroys the seeds or heads of grain. Seed treatment kills the smut on the seeds before they are planted.

Many farmers are in the habit of treating their wheat, but neglect to treat their oats or barley. Often there is more smut in oats and barley than in wheat.

Rye smut is rare in Manitoba, and, therefore, rye usually need not be treated for smut.

Wheat, oats and barley should be treated for smut, as it is a cheap insurance against loss from this cause. If there was smut in the field last season, there will be smut in the crop sown from the seed, unless it is treated. Also smut sometimes gets upon the seed in the thresher.

All oats smut can be prevented by seed treatment.

Bunt of wheat (also called covered smut, stinking smut, and ball smut) may be prevented by seed treatment. Covered smut of barley may also be prevented by treatment.

There is also a loose smut of wheat and a loose smut of barley. These smuts are discussed briefly on the last page. Neither of these two smuts can be prevented by ordinary seed treatment.

SUBSTANCES TO USE FOR SEED TREATMENT

Use formalin for oats smut and covered smut of barley.

Use formalin or copper carbonate for bunt smut of wheat.

Formalin can be obtained everywhere, and is in common use.

Copper carbonate is now on the market in many places. It is a fine, greenish powder, and should contain about 20 per cent. of copper. It is not necessary that there be more than 20 per cent. of copper.

Blue stone, or blue vitriol, is still sometimes used for treating wheat. Formalin or copper carbonate is better. Blue stone should never be used for oats or barley.

METHODS OF USING FORMALIN

Obtain formalin in bottles or stone jugs. It should be nearly forty per cent. strength, as is usually marked on the label. There are several methods of treating grain. We will outline the sprinkling method first. Formalin should be used just before the grain is sown.

SPRINKLING.—Pour a pound bottle into a barrel of water (about 35 to 40 gallons), for about 50 bushels of seed. Or use a cupful of the formalin to about 20 gallons of water (a pail holds 2 or 3 gallons of water) for about 25 bushels of seed. Use two tablespoonfuls of formalin to a pail of water if only 3 or 4 bushels are to be treated.

Spread the grain out (after fanning) on a clean granary floor or wagon box until it is only about 4 to 6 inches deep.

Sprinkle the diluted formalin over the grain by means of a sprinkling can (or a broom may be used). Then shovel or rake the grain over and sprinkle again, until all the grain is moist. (This will take nearly a gallon

to the bushel.) Where a smut machine is available it can be used to good advantage.

Shovel the grain into a pile and cover it carefully with old carpets, blankets, tarpaulin or other cloth cover to keep the fumes in. Leave the cover over for 2 to 10 hours, then spread the grain out to dry for a short time, or sow at once, setting the drill to allow for the swollen grain. The grain should always be sown soon after treatment with formalin, because of the danger of some seed injury (particularly to wheat) if the formalin dries on the grain.

Do not allow the grain to freeze, heat, sprout or mold by remaining wet.

DIPPING.—Another method that may be used is the dipping method, if sacked grain is used. The sacks should not be very full, and are dipped into the barrel or vat of diluted formalin, pulled out and allowed to drain a moment, then dipped in again, and so on until the grain in the center of the sack is wet. Then plant as soon as possible.

Barley stripe, one of the more injurious diseases of barley, may be prevented also by giving the barley seed a soak of about one-half hour in the formalin solution.

SPRAYING.—For oats only, a method may be used which does not wet the grain. For this it is necessary to get a small garden atomizer costing about $1.00. (A sprinkler will not do.) Equal parts of pure formalin and water are used. This strong mixture is placed in the atomizer and sprayed over the grain, which is spread out. A pint of the mixture is enough for 25 bushels of oats—do not use more. Keep the atomizer fairly close to the oats to avoid the uncomfortable fumes. Then shovel the grain at once into a pile, and cover about 4 or 5 hours. Then plant at once.

DON'TS WITH FORMALIN

Don't pour a little pure formalin into a sack of grain and then tie up the sack. This kills considerable of the seed, and does not properly prevent the smut.

Don't use too much formalin in the mixture, or the grain may be injured.

Don't treat grain with formalin until you are ready to plant.

METHODS OF USING COPPER CARBONATE

The copper carbonate method is an entirely different way to treat grain: it is a dust treatment, and the wheat is never wet. Treatment may be done at any time. (In fact if the wheat is treated early it is largely protected against injury by rats and mice.) Copper carbonate is not satisfactory upon seeds with a hull, so should be used only for wheat or hull-less oats or barley. There is required, first of all, some type of mixing machine by means of which the dust is coated over all the grain. **Copper carbonate should never be mixed with grain by shoveling:** it is ineffective, and the operator will breathe in too much of the copper dust.

Machines for dust treatment may be purchased, or may be made at home. A tight barrel may be used. One or two baffle boards 3 or 4 inches wide should be firmly nailed edgewise the full length of the barrel on the inside, to prevent the grain slipping around when being treated. Then put in the head of the barrel tightly, and bore a hole in the center of each head so that a 1½ inch iron pipe can be fitted tightly so as to serve as an axle to turn the barrel. Then the barrel must be firmly mounted on a rack. A crank is made at one end to turn the barrel. An opening about a foot in diameter must be sawed in the side of the barrel to put the grain in and to remove it. The cover must fit very tightly to prevent dust from escaping.

An old barrel churn can be used if baffle boards are put in.

To treat, fill the barrel about one-third full of wheat, add copper carbonate dust at the rate of 2 ounces per bushel, turn the barrel about 20 revolutions per minute for one and a half to two minutes, then remove the grain.

It is advisable to keep a wet cloth or handkerchief over the nose and mouth while treating with this dust, since it is irritating and injurious if breathed or swallowed.

ADVANTAGES OF DUST TREATMENT

The germination of seed is not injured; treated wheat may germinate better than untreated. Seed may be treated at any time before planting.

There is no swelling or wetting of seed.

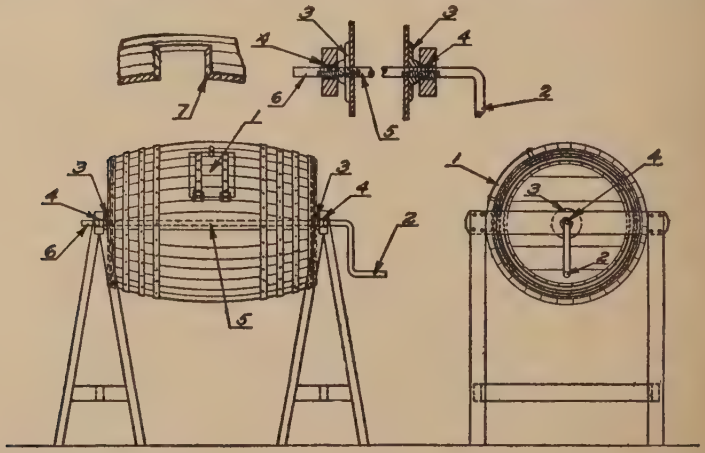
SOME DISADVANTAGES OF COPPER CARBONATE

Some sort of mixer is required.

The nose and throat must be protected by a dust mask while treating.

It is slightly more expensive than formalin.

Excess copper carbonate dust must be carefully and frequently cleaned from the drill, or the machine may be injured, or seeding may not go on properly. Treated seed must not be fed or sold on the market.



Barrel mixer for treating grain with copper carbonate. 1, Door to barrel; 2, crank; 3, disks screwed against heads of barrel to fasten it to axle; 4, threaded ends of axle; 5, axle; 6, axle extension for mounting in rack; 7, beveled cut in door (1) to prevent escape of dust.

THE LOOSE SMUTS OF WHEAT AND BARLEY

These smuts are fairly common in Manitoba. In both cases the whole head is destroyed, chaff and all, and finally only the bare stalk remains. These smuts "head out" before healthy heads, and are then conspicuous.

If loose smuts occur in wheat or barley, an effort should be made to get clean seed. Or a seed plot may be grown at some distance from other crops of the same kind, and smutted heads removed and destroyed when they first appear.

OTHER METHODS OF GROWING HEALTHY CROPS

Crop rotation is a valuable aid in avoiding diseases of field crops. Germs which cause plant diseases will increase in a soil growing the same crops too frequently. Good farming allows healthier crops to grow.

Use clean, vigorous, select seed.

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WINNIPEG, CANADA, FEBRUARY, 1928

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EXTENSION BULLETIN 88

Rusts and Smuts of Grains

(This bulletin is a revision of Extension Bulletins No. 44 and 71, and Circular 85, and is written for the reference of students in schools, and of Manitoba farmers who wish to increase the quality or quantity of crop production through the avoidance of certain plant diseases.)

Photo by Howitt

The Cluster Cup Stage of Stem Rust on a Barberry Leaf

By G. R. RISBY
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and
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Professor of Botany and Biology
Manitoba Agricultural College
Winnipeg, Manitoba

PLEASE
if of no value
to someone
may be inter

Printed by authority of Hon. A. Prefontaine, Minister of Agriculture and Immigration

Rusts and Smuts of Grains

MOST of the diseases of cereals, such as rusts and smuts, are caused by fungi. Fungi are plants without stems and leaves, and without the leaf green (chlorophyll) which enables other plants to produce food in the light. Fungi must, therefore, live upon food already produced. Many fungi live upon (or within) and at the expense of living plants; these are called parasitic fungi, and they cause heavy losses of crops each year. Many other fungi obtain their food from dead organic matter; such fungi are termed saprophytic fungi, and are represented by most of the common mushrooms and puffballs that are so commonly seen in woods and fields in the summer, and by the moulds upon food exposed to the air in a damp place. Some fungi, such as the rusts, are able to develop only upon a living plant; others, such as those causing seedling blights, may also live on dead organic matter; still others, such as many of the mushroom fungi, cannot develop upon living plants. The saprophytic fungi may cause some damage from their growth upon food or lumber, for example: but their useful qualities far outweigh their injurious ones. They rot the dead leaves and fallen twigs and trunks of the trees in a forest, and thus form leaf mould, which can again be used as food by the trees; in fields they gradually decompose the stubble and weeds which are plowed under. It is evident that farming could not go on for long if the mass of plants and plant parts that is plowed under each year did not decay, and thus release plant food that previous plants had taken from the soil, and help to keep the soil in good tilth. All green plants require light in order to grow; but the fungi are not dependent upon light, and may be found in dark cellars or within the soil.

Figures 1, 2 and 3

Instead of stems and leaves, fungi produce a thread-like growth called mycelium. This cottony growth can be seen in various moulds. In mushrooms the mycelium is often called "spawn." The mushroom itself is made up of large numbers of mycelial threads growing side by side. In many parasitic fungi the mycelium is within the stem, leaves or other part of the plant, and cannot be seen without a microscope. Fungi produce, instead of seeds, very small bodies called spores. These are so small and light that they may be carried in the air for considerable periods. Figure 1 shows a common mould much magnified; at the bottom is seen a little of the mycelium with finer root-like branches, and above, cases bearing spores which are produced in large numbers within it. Figure 2 illustrates the miroscopic appearance of the green mould which grows on lemons and other fruits, foods, etc. At the bottom is shown the root-like

growth of the mycelium within the lemon or other organic matter; at the top the spores are produced in rows upon the ends of finger-like processes. Figure 3 illustrates, enlarged, the tiny black dots which appear in the mildews. Each "dot" bears projections with branched ends, and contains little sacs containing spores. These spores live over winter within the cases and some of them blow, or are carried by insects, to the proper plant in the spring, where the spores germinate and start the mildew again.

The drawing of Ergot (Figure 4) gives an idea of the complex life of certain fungi. The black ergot bodies (A, B) fall from grass or rye plants to the ground, where they live over winter; in the spring they germinate by producing several reddish "heads" (C); each of these bears many pits (D) each of which is filled with sacs containing spores (P). These spores escape through openings and some of them are blown upon grass or rye blossoms, where they attack the young seeds and produce many sticky spores which are carried to other plants by insects; then the ergot bodies (A) are again produced in place of seeds.

Fig. 4—Life History of Ergot.

It may give an idea of the size of spores produced by fungi to note that a single kernel of wheat affected with bunt may contain from eight to twelve million spores.

Many people believe that weather produces disease in plants; for instance, that damp, warm weather produces wheat rust. This is true only in the sense that the spores of the rust fungus can germinate and cause infection only in the presence of moisture, and that the fungus develops more rapidly when the weather is warm. Weather conditions, such as frost or long drought, may injure plants, but most plant diseases, like animal or human diseases, are caused by living organisms; and cannot occur unless the "germ" is present.

Much effective work is now being done upon Cereal Diseases in western Canada. The new Dominion Rust Research Laboratory, located at the Manitoba Agricultural College, has a good staff of workers under the general direction of Dr. D. L. Bailey, who are carrying on excellent work on rusts, smuts, and other cereal diseases. Other workers in the Prairie Provinces are engaged in the important work of seeking remedies for rusts and smuts, and we of course also have the advantages of any discoveries made in the United States or elsewhere. Several grain growers are also endeavoring to obtain resistant varieties of grain. This bulletin is revised in the light of the discoveries made during the past five years.

PART I

Rusts

GENERAL DISCUSSION; KINDS OF SPORES

Rusts of grains occur in every country in the world, and have been observed for two thousand years. Most of our knowledge has, however, been obtained during the past few years. The most important rust is stem rust (often called black stem rust; *Puccinia graminis*). The greatest damage by this rust occurs upon wheat, but oats, barley, rye and several grasses are also attacked. Stem rust is found not only upon the stems, but also upon the leaves, sheaths, chaff, beards, and sometimes even on the grains. The roots of plants are not affected.

The life of a rust is complex. There are five different kinds of spores produced. "Red rust" and "black rust" are two of these: they are two of the stages in the life of the same rust. The common belief that black rust causes more damage than red rust is not quite correct; the black rust occurs after the grain is weakened from the attack of the red rust; black rust *reflects* the damage, but red rust *causes* much of it.

The five different kinds of spores are as follows:

(1) The red rust spores, which break through the stems or leaves of the grain plant producing the familiar rough spots. These spores are brick red in mass, and may be produced by billions, and rise in clouds around the binder. The wind carries them from affected plants to other plants, often miles away. When these small, oval spores fall upon another proper grain or grass plant, and moisture is present, they germinate as shown in Figure 5 and produce a "sprout" which grows into the leaf or stem through the small breathing pores. Moisture (dew or rain) must be present, and the temperature must be about 45° F. or higher. In one warm, moist night the spore can germinate and start its mycelium within the host plant; this mycelium continues to grow at the expense of the plant for eight to ten days, and then it breaks through the surface to form another crop of red spores. The red spores may live a month in summer, or six months during the winter. Late in the season or after the grain plant is injured by rust, the mycelium may produce black spores instead of red spores, but the red spores never change over into black rust spores.

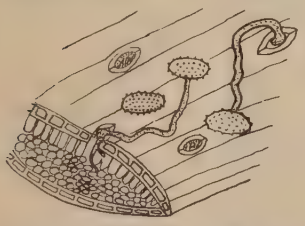


Fig. 5—Diagram to illustrate the germination of red spores on a cereal leaf, and the entrance of the germ tubes through the breathing pores of the leaf.

(2) The black spores of stem rust also break through to the surface, but they do not become detached from the plant. They live over winter; in fact they will not germinate until the spring after they are formed. Black spores will not attack cereals or grasses. Under a microscope, the black spores are seen to be composed of two parts, or cells; Figure 6 illustrates these spores and their method of germination in the spring.

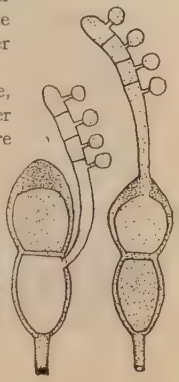


Fig. 6—The black spores of stem rust have two parts (cells), either or both of which may germinate in the spring and produce four small spores, which can infect only the barberry.

(3) The black spore which germinates on old stubble, straw, or grasses produces a short tube which bears four small spores called basidiospores or sporidia (Figure 6). These

are shot off and are carried about by air currents. Most of them fall finally to the ground, or alight on plants that they cannot attack, and die. These spores will not develop on cereal or grasses, but only upon the cultivated barberry. If one of these spores should chance to reach a barberry leaf, it germinates and grows through the leaf.

(4) Upon the upper surface of the barberry leaf are produced small spherical structures called pycnia (Figure 7). The pycnia secrete a sweet fluid containing many small pycnospores. The sweet exudate attracts insects, which carry the spores to other pycnia, where they act to stimulate the formation of cluster cups.

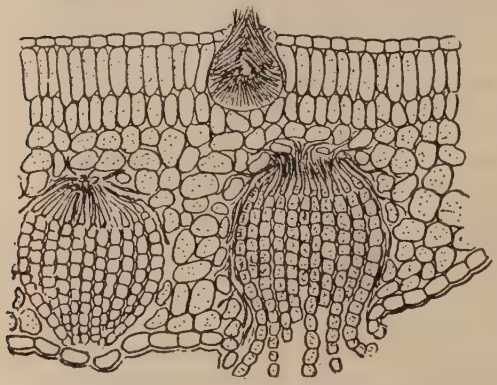


Fig. 7—Section of Barberry Leaf, showing the clustercup stage of Black Stem Rust of Wheat.

(5) The cluster cups are produced on the lower surface of barberry leaves from the mycelium within the leaf (Figure 7 and front cover). Each "cup" produces about ten thousand spores. These escape from the cups and are carried about by air currents; these spores will not attack the barberry, but only certain cereals or grasses. If the black rust, which produced the basidiospores which finally produced the cluster cup spores, was on wheat, then the cluster cup spores will also attack wheat, but not oats or rye. On the wheat the mycelium from the germinating cluster cup spores produces red spores which start the cycle over again.

BARBERRY BUSHES AND RUST

It has been noted by farmers for more than two hundred years that rust is worse near barberries. We have just explained why. During the past ten years practically every barberry bush in the Prairie Provinces has been destroyed, and also some 15,000,000 of these bushes in the spring wheat states just south of us. Figure 8 (see page 7) illustrates the common barberry which carries rust. It is not a native plant, and grows here only when planted in gardens or hedges. The Japanese, or small-leaved, barberry does not rust. There are still many barberries in the states just south of us, and some of the rust that reaches us comes from these. But since our barberries have been destroyed, and those in the states are being eradicated, we need not dwell upon the barberry. A Dominion Act dated June 4, 1923, prohibits the importation into the Prairie Provinces of rust-carrying species of common barberry, and the European buckthorn which carries leaf rust of oats.

Where does our rust come from? We have just seen that rust may come from barberries in the spring, but the destruction of the barberry bushes is removing this source of danger. There remain only two possible sources for the rust which appears each year in Manitoba. These are:

1. From red rust overwintering here.
2. From red rust spores blowing in from the south.

It may be emphasized again that rust does not come from the seed grain; weather conditions alone cannot produce rust; that the black rust on straw or grasses cannot attack grasses directly.

Regarding the first possibility, very extensive tests have shown that few, if any, of the red spores survive our winters, so as to start the rust in the spring here.

There is, on the other hand, ample evidence that the rust does blow in each spring. If a glass slide coated with some sticky substance be exposed in the air, the red spores which fall upon it will be caught, and can then be counted under a microscope. Tests made by the Rust Research Laboratory in 1925 showed that about 270 red spores fell on each square inch of land surface during the last half of July. This red rust blows into Manitoba from Minnesota and North Dakota, and into these states from other states further south. In Mexico or Texas or other southern states the red rust commonly lives over winter on winter wheat. Manitoba has a worse rust attack than Alberta, or even Saskatchewan, because Manitoba joins on the south to a great central wheat growing area. It will also be evident that the rust does not necessarily produce all the five kinds of spres previously listed: the red stage can repeat indefinitely. We cannot prevent the rust blowing into Manitoba; but any measures the growers can take in the states south of us to lessen rust, will help us also by lessening the amount of rust that may blow in.

THE VARIOUS FORMS OF STEM RUST

The stem rust occurring upon wheat, oats, barley, rye, and the various wild grasses looks much the same from each plant, and is all considered to be the same species of rust. But this rust fungus is specialized so that the rust on wheat will not attack oats or rye, and vice versa. These forms are called physiologic or biologic forms. The following forms are known in North America:

Fig. 8—The Noxious Weeds Act calls for the destruction of the Common Barberry (*Berberis vulgaris* and its varieties). This includes all the large, three-pronged, spiny-leaved varieties the purple leaved, the white, yellow, purple, red and black berried kinds. Only the small-leaved Japanese varieties (*B. thunbergii*) are immune.

1. The wheat form, Puccinia graminis tritici, attacks wheat, barley, and several wild grasses such as wild barley, western rye-grass, wild rye, and lime-grass. The wheat form is further specialized as noted later.

2. The oats form, Puccinia graminis avenae, goes to oats, wild oats, orchard grass, and a few other grasses. It also is further specialized on varieties of oats.

3. The rye form, Puccinia graminis secalis, attacks rye, barley, wild barley, couch grass, and a few other grasses.

4. The timothy form, Puccinia graminis phleipratensis, goes to timothy, orchard grass, fescue grass, meadow foxtail, and crested hair-grass. This is the only form of the rust that does not attack the barberry.

5. The red-top form, Puccinia graminis agrostis, attacks red-top, orchard-grass, and a few other grasses.

6. The blue-grass form, Puccinia graminis poae, attacks blue-grass and other species of Poa. This is the only form that has not been found in Manitoba.

It will be noted that barley does not have a special form of the rust, but is rusted by either the wheat or rye form. These various forms of rust seem to remain constant, but it is possible that they may sometime change slightly.

WILD GRASSES AND RUST

We have just recorded the fact that each form of rust may go to several wild grasses. Sometimes these wild grasses are badly injured by rust, as can often be seen in the case of wild barley or foxtail. Wild grasses serve to increase the amount of rust, and such weeds as wild barley should be destroyed so far as possible. But wild grasses are not essential to the development of the rust of grains.

WEATHER CONDITIONS AND RUST

Everyone knows that rust is likely to be worse after periods of damp, warm weather in summer. This is true because the rust requires moisture to germinate and get into the plants, and it develops much faster in warm weather. When the temperature remains below about 45° F. at night, the rust does not develop. It will not develop above about 85° F. On the whole, our summer climate is very favorable for the development of rust.

THE PREVENTION OF RUST

No method of seed treatment can prevent rust, except insofar as the treatment might produce earlier or stronger germination and thus allow the grain to mature a little earlier. A farmer can do little to prevent rust by adding fertilizer or other chemicals to his soil; in fact manure makes for ranker growth and more rust if it be applied heavily before the grain crop.

Most farmers know and try to utilize certain agricultural practises which tend to lessen the severity of rust. Professor Ellis suggests these in Manitoba Bulletin 41:

1. Sow early and use good seed, to bring about earlier maturity.
2. Sow more thickly on rich soils, such as summerfallow.
3. Prepare a good seed bed and sow at an even depth.
4. Do not harrow growing grain; this delays maturity.
5. Apply any manure evenly and lightly.
6. Poorly drained areas, or places where plants cannot be dried off by the wind, are apt to show more rust.
7. Soil drifting is likely to delay maturity and increase rust.
8. Badly rusted grain can best be cut when the kernels are so firm that they cannot be crushed by the fingers.

In addition to these measures, many farmers in Manitoba, particularly in the southwest, have found that Durum wheats, especially Mindum, withstand rust much better than most bread wheats. Several varieties of bread wheat having more resistance than Marquis, or maturing earlier than Marquis, have been tried, and some of these are promising.

The best hope of solving the rust problem lies in the production of resistant varieties of grain. Much effort is being made along this line by government workers and by wheat breeders everywhere. The problem is extraordinarily difficult. But much progress has been made, and the problem will doubtless eventually, perhaps soon, be solved.

The dusting of grain with sulfur has been shown to be effective in preventing rust. Several applications are usually necessary, and experiments are being carried out to determine the practicability of this method. Those interested should write the Rust Research Laboratory, Manitoba Agricultural College, Winnipeg, for details. The tests made in 1927 with airplanes suggest that large acreages may possibly be dusted effectively by this means.

LEAF RUSTS

In addition to stem rust, each of the four cereals may have a leaf rust. Leaf rusts do not attack the stems, but stem rust does attack the leaves. Leaf rusts often appear before stem rust; the red stage is more orange in color than that of stem rust, and the spots usually smaller, and do not tear the leaves much as they break through. The leaf rust of oats may be very injurious, as was the case in 1927, and the leaf rust of wheat is sometimes injurious. Leaf rusts of rye and of barley are not serious. Leaf rusts are discussed under the crops they attack.

RUSTS OF OTHER CROPS

Many wild plants, such as roses, cinquefoil, gooseberries, blue lettuce, golden-rod, etc., are attacked by rust. These rusts of wild plants have nothing to do with the rusts of grains. We have records of 120 different rusts in Manitoba. Only those discussed in this bulletin occur upon cereals here.

PART II

Smuts of Grains

Smuts cause heavy losses of wheat, barley, and oats. The loss comes not only from the grain destroyed but also from the dockage on smutty grains. Much of these losses can be prevented by proper seed treatment.

Fig. 9

A —A head of Prelude showing 14 bunt balls. The stinking or covered smut of wheat.
B —The loose smut of wheat—has destroyed all the kernels.

Smuts are caused by fungi which infect the grain through the seed or through the plant and destroy the heads or kernels. The black smutty appearance of affected heads is due to the presence of millions of smut spores, each one a small round particle only one-thousandth to one five-thousandth of an inch in diameter. If smut gets started in a field, it is likely to increase unless treatment is used to stop it. Smut may sometimes get on the seed from threshing machines, or smutty drills or sacks.

KINDS OF SMUTS

1. Smuts that can be prevented by ordinary seed treatment, such as formalin, include bunt or stinking smut of wheat, covered smut of barley, oats smut, and smuts of millet and western rye-grass. In these smuts the spores cling to the grains or their hulls over winter. The spores get on the seeds in the field, in the thresher, or in other handling. In "tagged wheat" the smut spores may be seen as a black smudge, especially at the brush end. When seed carrying these spores on the surface is planted without treatment, the smut spores germinate at the time the grain germinates, and sprouts from the smut spores grow into the young grain seedling in the soil. The smut grows up inside the plant without showing, until the grain heads out, whereupon smut is produced instead of grain.

2. Loose smuts of wheat and barley cannot be effectively prevented by ordinary seed treatment, but require a hot water treatment. These two loose smuts destroy not only the seeds, but all the chaff as well. Smutted heads appear in the fields just before the healthy plants head out, and as the healthy heads are in bloom, smut spores from the affected heads may blow into the blossom of the grain, and the spores germinate then and there and a little of the mycelium of the loose smut fungus grows into the young grain. The affected seeds appear normal, however, and are prefectly good for bread-making or feeding. But if affected seeds are planted, the smut within the kernel grows up with the sprouting grain and finally produces smutty heads again. Growers must recognize that there are two kinds of smut on wheat and two on barley, and that the loose smut may develop on seed treated with formalin, bluestone, or copper carbonate.

3. Corn smut is not carried by the seed, and cannot be prevented by any seed treatment. This smut lives over winter in the soil, or in manure piles, and affects any above ground part of the corn plant.

SUBSTANCES TO USE FOR SEED TREATMENT

Use formalin for oats smut and covered smut of barley.

Use copper carbonate dust or formalin for bunt or ball smut of wheat.

Formalin is obtainable everywhere in bottles or stone jugs. It should be about 40 percent strength, as is usually marked on the label.

Copper carbonate is obtainable at most hardware stores. It is a fine greenish powder, and is used dry. It should contain about twenty percent of copper.

A solution of blue stone, also called copper sulphate or blue vitriol, is still used by some farmers for treating wheat. It should not be used, for it is too liable to cause injury to the seed.

METHODS OF USING FORMALIN

There are several methods of using the formalin treatment. Grain should always be sown as soon as possible after treatment with formalin.

1. Formalin sprinkle is effective against all our smuts except loose smuts of wheat and barley. It is recommended for covered smut of barley and oats smut. Pour a pound bottle into a barrel of water (about 35 to 40 gallons), for about 50 bushels of seed. Or use a measuring cup of the formalin to about 20 gallons of water (a pail holds 2 or 3 gallons of water) for about 25 bushels of seed. Use two tablespoonfuls of formalin to 2½ gallons of water if only 3 or 4 bushels are to be treated.

Spread the grain out (after fanning) on a clean granary floor or wagon box until it is only about 4 to 6 inches deep.

Sprinkle the diluted formalin over the grain by means of a sprinkling can (or a broom may be used). Then shovel or rake the grain over and sprinkle again, until all the grain is moist. (This will take nearly a gallon to the bushel.) Where a smut machine is available it can be used to good advantage.

Shovel the grain into a pile and cover it carefully with old carpets, blankets, tarpaulin or other cloth cover to keep the fumes in. Leave the cover over for 4 to 10 hours, then spread the grain out to dry for a short time, or sow at once, setting the drill to allow for the swollen grain. The grain should always be sown soon after treatment with formalin, because of the danger of some seed injury (particularly to wheat) if the formalin dries on the grain.

Do not allow the grain to freeze, heat, sprout or mold by remaining wet.

Dipping—Another method that may be used is the dipping method, if sacked grain is used. The sacks should not be very full, and are dipped into the barrel or vat of diluted formalin, pulled out and allowed to drain a moment, then dipped in again, and so on until the grain in the centre of the sack is wet. Then plant as soon as possible.

Barley stripe, one of the more injurious diseases of barley, may be prevented also by giving the barley seed a soak of about one-half hour in the formalin solution.

Spraying—For oats only, a method may be used which does not wet the grain. For this it is necessary to get a small garden atomizer costing about $1.00. (A sprinkler will not do.) Equal parts of pure formalin and water are used. This string mixture is placed in the atomizer and sprayed over the grain, which is spread out. A pint of the mixture is enough for 25 bushels of oats; do not use more. Keep the atomizer fairly close to the oats to avoid the uncomfortable fumes. Then shovel the grain at once into a pile, and cover about 4 or 5 hours. Then plant at once.

Don'ts with Formalin—Don't pour a little pure formalin into a sack of grain and then tie up the sack. This kills considerable of the seed, and does not properly prevent the smut. Don't use the gas grain pickler method.

Don't use too much formalin in the mixture, or the grain may be injured.

Don't treat grain with formalin until you are ready to plant.

METHODS OF USING COPPER CARBONATE

The copper carbonate method is an entirely different way to treat grain; it is a dust treatment, and the wheat is never wet. Treatment may be done at any time. (In fact if the wheat is treated early it is largely protected against injury by rats and mice.) Copper carbonate is not satisfactory upon seeds with a hull, so should be used only for wheat or hull-less oats or barley. There is required, first of all, some type of mixing machine by means of which the dust is coated over all the grain. Copper carbonate should never be mixed with grain by shovelling: it is ineffective and the operator will breathe in too much of the copper dust.

Machines for dust treatment may be purchased, or may be made at home. A tight barrel may be used. One or two baffle boards 3 or 4 inches wide should be firmly nailed edgewise the full length of the barrel on the inside, to prevent the grain slipping around when being treated. Then put in the head of the barrel tightly, and bore a hole in the center of each head so that a 1½ inch iron pipe can be fitted tightly so as to serve as an axle to turn the barrel. Then the barrel must be firmly mounted on a rack. A crank is made at one end to turn the barrel. An opening about a foot in diameter

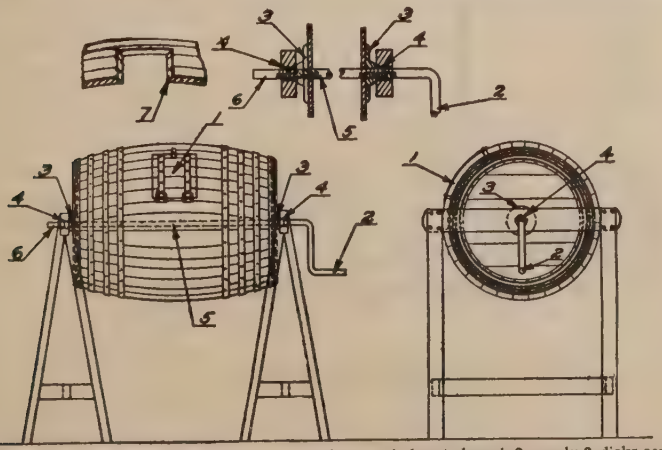


Fig. 10—Barrel mixer for treating grain with copper carbonate. 1, door to barrel; 2, crank; 3, disks screwed against heads of barrel to fasten it to axle; 4, threaded ends of axle; 5, axle; 6, axle extension for mounting in rack; 7, beveled cut in door (1) to prevent escape of dust.

must be sawed in the side of the barrel to put the grain in and to remove it. The cover must fit very tightly to prevent dust from escaping (Figure 10—page 11).

An old barrel churn could be used.

To treat, fill the barrel about one-third full of wheat, add copper carbonate dust at the rate of 2 ounces (two heaping tablespoons) per bushel, turn the barrel about 20 revolutions per minute for one and a half to two minutes, then remove the grain.

It is advisable to keep a wet cloth or handkerchief over the nose and mouth while treating with this dust, since it is irritating and injurious if breathed or swallowed.

ADVANTAGES OF DUST TREATMENT

The germination of seed is not injured; treated wheat may germinate better than untreated. Seed may be treated at any time before planting.

There is no swelling or wetting of seed.

SOME DISADVANTAGES OF COPPER CARBONATE

Some sort of mixer is required.

The nose and throat must be protected by a dust mask while treating.

It is slightly more expensive than formalin.

Excess copper carbonate dust must be carefully and frequently cleaned from the drill, or the machine may be injured, or seeding may not go on properly. Treated seed must not be fed or sold on the market.

PREVENTION OF LOOSE SMUTS OF WHEAT AND BARLEY

Where these smuts occur, efforts should be made to obtain seed known to be free from loose smut. It is an excellent plan to grow a seed plot at some distance from other fields of the same kind, and carefully remove and destroy all smutted heads as soon as they appear. Loose smut heads come out just before the healthy heads. A seed plot also permits the removing of mixtures of varieties, etc.

Fig. 11—Hot water treatment for loose smut of barley. For loose smut of wheat have the water in the centre barrel at 129 degrees F.

Loose smut of barley may sometimes be prevented somewhat by formalin but loose smut of wheat and most of the loose smut of barley, may be prevented by no seed treatment except the use of heat, such as hot water. This treatment is slow and risky. An absolutely accurate, tested thermometer must be used. Where steam is available barrels may be set up as indicated in figure 11. The wheat seed must be soaked in hot water at 129° F. for 10 to 15 minutes, and the barley 15 minutes at 126° F. Soak the seed first in warm water, as indicated in the diagram. After treatment spread the grain out to cool and dry, and then sow it in a seed plot to secure healthy seed for the year after.

PART III

Diseases Listed by Crops

The foregoing pages have presented general considerations regarding rusts and smuts. The following pages deal more specifically with these and other diseases of the various cereals. Any observant grower will find that there are several plant diseases more or less conspicuous, in his crops. Some of these diseases are not yet serious.

WHEAT DISEASES

1. Stem Rust, caused by *Puccinia graminis tritici*. This form of rust is further specialized upon different varieties of wheat. More than 40 different forms of wheat rust are now known; about 20 forms have been found in Western Canada. During the past three years forms numbered 21 and 36 have been the commonest. The table below indicates the way in which these two forms attack the various hosts which are used to differentiate forms of wheat rust:

Variety of Wheat Emmer, Etc.	*Kind of Attack Form 21*	*Kind of Attack Form 36*
Little Club	Heavy infection	Heavy infection
Marquis	Heavy infection	Heavy infection
Kanred	Nearly immune	Heavy infection
Kota	Moderate infection	Moderate infection
Arnautka (Durum)	Heavy infection	High resistance
Mindum (Durum)	Heavy infection	High resistance
Speltz Marz	Heavy infection	Nearly immune
Kubanka	Heavy infection	Mixed infection
Acme	Moderate infection	Moderate infection
Einkorn	Resistant	Moderate infection
Emmer (Vernal)	Nearly immune	Nearly immune
Khapli (Indian Emmer)	High resistance	High resistance

It will be seen from the above table that the attack of the two rusts differs on Kanred, Arnautka, Mindum, Speltz Marz, Kubanka and Einkorn. Form 21 attacks durums rather heavily, but nevertheless they withstand such attacks better than do bread wheats. The plant breeders are endeavoring to combine resistance to the prevalent forms of wheat rust, with good yielding, milling, and baking qualities.

2. Leaf Rust, caused by *Puccinia triticina*. This rust is often abundant, and sometimes causes considerable damage. But it never causes losses of wheat approaching those caused by stem rust. Sulfur dusting lessens this rust as well as stem rust. The red spores live over winter here or to the south. This rust does not attack the barberry, but Asiatic species of Meadow Rue. Leaf rust of wheat is not especially to be feared. Plant breeders are attempting to obtain wheats that are resistant. Leaf rust of wheat will not attack other cereals.

3. Bunt, ball smut, covered, or stinking smut, caused by *Tilletia tritici* or sometimes by *Tilletia laevis*. This disease is common where seed treatment is neglected. Newer agricultural areas are likely to show heavier infections than are found in the older settled regions. Copper carbonate dust or formalin will prevent this smut, and should be used except in those rare cases in which a grower can feel sure he has none of this smut or that his grain has not become infected in threshing or other handling.

4. **Loose smut,** caused by *Ustilago tritici*, is fairly common in Manitoba. Wheat growers should observe their fields carefully soon after the wheat starts to head out, in order to determine how much loose smut is present. Methods of avoiding this disease have been given.

5. **Root rots,** caused by *Helminthosporium*, *Fusarium* and *Ophiobolus*. These fungi commonly live over winter in the soil, but may also sometimes be carried by the seed. Considerable damage is caused, and the symptoms are various. The most conspicuous injury is that in which full grown plants are blighted, and the heads fail to fill on account of the injury to the roots. Durum wheats are especiallly likely to show this disease, but bread wheats also often suffer from it. This trouble is bad in certain years, and not very serious in other years. It is likely to be worse when weather conditions are unfavorable to the wheat, especially when the temperature and moisture are too high.

Seedling blights, in which the wheat is killed or stunted before or soon after it appears above ground, is another symptom caused by these fungi.

Blackening of the stem, or the nodes, black point of kernels, and some spotting of leaves, are also caused by the same fungi. The area of the stem near the ground line is particularly likely to show injury.

The accumulation of these root rotting fungi in the soil is one of the penalties of too continuous wheat growing. Good crop rotations, good clean seed, proper handling and preparation of the soil, seed treatment, and other agricultural practises which make for vigorous, healthy growth of the wheat, will tend to reduce these troubles.

"Take all" is a name sometimes given to the attack by *Ophiobolus graminis*.

6. **Scab,** or **"Pink heads,"** caused by *Gibberella saubinetii*. This disease is injurious in warmer, moister regions southward, and is sometimes found in Manitoba. Affected heads show whitish areas which may enlarge to include the whole head, and the chaff often shows a pink tinge from the growth of the fungus. The seeds are shrivelled and pale. Seedling blight may occur when seed from scabby heads is planted. The use of healthy, plump seed, crop rotation and seed treatment will lessen this trouble. Corn may be attacked by the same fungus, and wheat following corn may sometimes show somewhat more of scab.

MINOR DISEASES OF WHEAT

7. **Glume blotch,** caused by *Septoria nodorum*, is sometimes very conspicuous. The chaff turns brown, and may show minute black dots. It is common in wet seasons. This trouble is much less serious than the appearance of the heads would indicate, but sometimes the kernels are somewhat shrunken or browned when the disease is abundant. Crop rotation would lessen glume blotch.

8. **Ergot,** caused by *Claviceps purpurea*, is seldom found on bread wheats, but may be injurious to durum wheats. Rye is most seriously affected, and ergot is discussed under rye.

9. **White tip** is caused by weather conditions. In hot, dry, windy weather the tips of the developing wheat heads may fail to fill, and turn white. White tip may also be found on very dry soil. Nothing can be done to prevent it, except the utilization of methods which conserve the water supply: white tip is much less common on summer-fallow.

10. **Black chaff,** caused by *Bacterium translucens undulosum*, produces a blackening of the glumes similar to that caused by glume blotch. It has not been found to be serious.

11. **Basal glume rot** is a similar type of disease caused by *Bacterium atrofaciens*. In this the lower part of the chaff is affected. It has not been found to cause much injury.

12. **Leaf spots** caused by *Septoria, Helminthosporium* and other fungi bring about considerable injury to wheat leaves, but the damage is not great.

13. **Rotting or moulding** of the heads in the stook in wet weather is caused principally by a number of saprophytic fungi. Everyone realizes the damage which prolonged dampness may cause to wheat in the field after harvest.

14. **"Crinkle joint"** is a condition commonly found in wheat in which there is a kink or bend in the lower part of the stem. It is often confused with hail damage, but is probably caused by the wind or sometimes the stem may have been weakened by fungi. It appears to cause no serious injury, but must be distinguished from the bruises and breaks caused by hail stones.

15. **Frost** may ruin wheat fields, as everyone knows. It is sometimes rather difficult to determine whether or not grain has been injured by frost, but cases in which the field fails to continue to ripen, and the plants have a dull appearance, are likely to have been brought about by frost.

OAT DISEASES

1. **Stem rust,** *Puccinia graminis Avenae,* may cause much injury. Six forms of the oats stem rust are known, and some of them will attack all the common varieties of oats.

2. **Leaf rust or crown rust,** *Puccinia coronata,* may be as serious as stem rust on oats. Both rusts were very injurious in 1927. The cluster-cup stage of this rust occurs on the cultivated European buckthorn, and the rust is worse in the vicinity of these buckthorns. The name crown rust is given because of the crown-like prongs which occur at the top of the black spores. The black stage remains covered by the epidermis of the oats leaf. Little can be said regarding prevention of rusts on oats, other than the general remarks previously given.

3. **Smuts,** caused by *Ustilago avenae* and *U. levis.* Although there are two smuts on oats, differing in their effect upon the head and in the appearance of the spores, they were treated as one in the discussion of seed treatment since they can both be prevented by formalin. The prevalence of smut in oats indicates that seed treatment should be more commonly applied to oats.

4. **Blast,** or **spikelet sterility,** is characterized by the failure of some of the kernels to develop. It is more prevalent when early favorable weather conditions are followed by dry or otherwise adverse weather. This trouble is not carried by the seed, is not infectious, and is not serious.

5. **Leaf spots, seedling blights** and **root rots** may also be found upon oats. The leaf spots may cause some injury but root rot troubles are not serious in oats. Crop rotation, seed treatment, and other good agricultural practises tend to lessen oats diseases—just as with other crops.

RYE DISEASES

1. **Stem rust,** *Puccinia graminis secalis,* may occur upon rye, but the crop usually matures before much damage is produced.

2. **Leaf rust,** *Puccinia dispersa* is common but seldom injurious. Rye is the only plant attacked by this rust in Western Canada.

3. **Ergot,** caused by *Claviceps purpurea.* Ergot is the familiar purplish, black, hard fungus which replaces the rye kernels. The life history of this fungus has already been outlined. The rye heads are attacked while they are in bloom. Damage is caused not only by the loss of rye kernels that are replaced by ergot, but also by the blighting of kernels where ergot bodies do not occur. Ergot is poisonous if taken in quantity by stock or people; but the drug made from ergot is useful in medicine. Ergot is even more common on various wild grasses than it is on rye. These wild grasses should, if possible,

be cut before the ergots appear. Durum wheat sometimes shows considerable ergot, and it is occasionally found upon barley. The ergot bodies over-winter on the soil where they fall from rye or grasses, and rye should, therefore, be rotated. Ergots die in granaries over winter, so that old rye seed with ergot is perfectly safe to plant. Ergots may be floated from rye seed by immersing it in about a 20% solution of common salt (about 2 pounds salt to the gallon of water), then stir and skim off the ergots and light seeds. Such treated grain should be placed in water afterwards to remove the salt.

4. **Rye smut,** *Urocystis occulta*, is occasionally found in rye fields in Manitoba. The stems and leaves, as well as the heads, are blackened by this smut. Formalin treatment will prevent it, and grain from affected fields should be treated.

Seedling blights, root rots, leaf spots, powdery mildew, winter injury, spikelet sterility and other minor troubles may sometimes be found upon rye, but in general rye is a fairly healthy crop.

BARLEY DISEASES

1. **Stem rust,** *Puccinia graminis tritici* or *P. graminis secalis.* Barley rust may come from either wheat or rye. Late barley is frequently badly rusted, but early sown barley may escape the rust.

2. **Leaf rust,** *Puccinia anomala.* Considerable was found during 1927. This rust is not likely to cause any particular damage.

3. **Covered smut,** caused by *Ustilago Hordei*, is common and injurious in Manitoba. The kernels and the chaff are both attacked, but the smut remains covered by a membrane until after harvest. The spore mass is black or purplish black. Formalin treatment should be used, as already described.

4. **Loose smut,** caused by *Ustilago nuda.* The powdery, olive-brown mass of spores which replaces the kernels and chaff is likely to blow away before harvest, leaving the blackened central stalk of the head. Formalin treatment may reduce this smut to some extent, but if much loose smut is present it would be advisable to obtain clean seed.

The surest way to distinguish the barley smuts is to observe the plants at heading time: loose smut heads out just before the healthy heads; covered smut just after the healthy.

5. **Stripe** caused by *Helminthosporium gramineum*, produces long brownish or yellow streaks on the barley leaves. Affected plants are stunted and killed. Stripe is common and often injurious. Stripe may be prevented by a soak of half to one hour in formalin solution, or by certain organic mercury disinfectants.

6. **Leaf blotches** and **seedling blights** caused by *Helminthosporia* may cause some injury to barley. The use of healthy seed, crop rotation, and seed treatment will lessen the danger from these troubles.

CORN DISEASES

1. **Smut,** *Ustilago Zeae.* This conspicuous disease causes some damage. Seed treatment is useless, because the spores are not carried by the seed, but may live over winter in the soil, or in manure piles containing the smut. The spores are soon killed in a silo. Crop rotation is important, and infected manure should be used with care.

2. **Rust,** *Puccinia Sorghi*, is fairly common on the leaves, but not injurious.

3. **Ear rots,** caused by *Basisporum gallarum* and other fungi, are fairly common, particularly on immature or improperly stored ears. Corn from infected ears should not be used for seed.

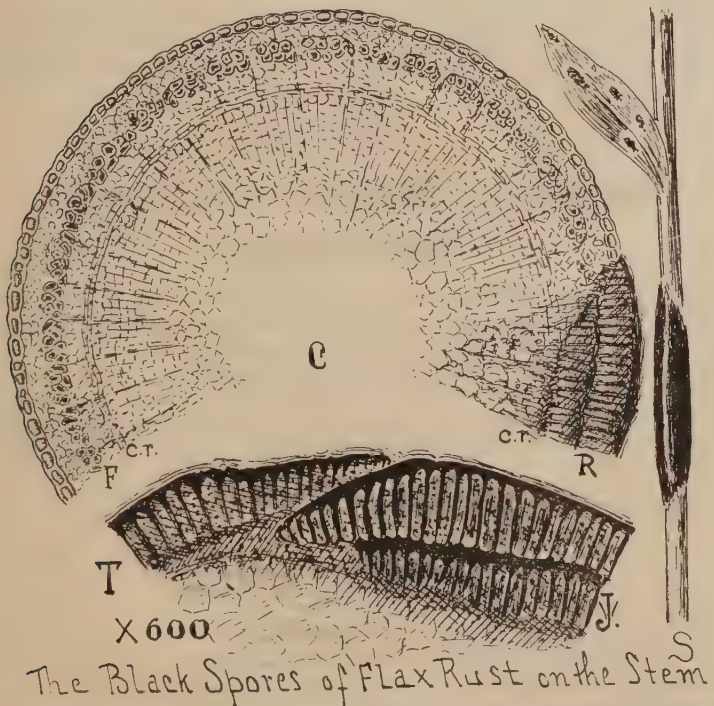
4. Corn and other salage may be destroyed, or sometimes rendered poisonous to stock, by **moulds** growing in the silage. The silo should be air tight, and the silage

packed well, so that moulds will not develop. It is a good plan to cover the silage with hay to lessen the moulding at the top. Care must be used in feeding mouldy silage.

FLAX DISEASES

1. **Wilt,** caused by *Fusarium lini,* is often serious on common flax. Flax on new breaking is not so liable to suffer as that on old land. Wilt resistant varieties, such as have been developed at the North Dakota Experiment Station, can be obtained and will usually prove resistant to wilt.

2. **Flax rust,** *Melampsora lini,* attacks the stems and leaves of flax, and often injures fibre flax. It is not generally serious on flax grown for the seed. Rust resistant varieties are being developed.



S—Flax stem with black spores and red spores on the leaf. C—Cross section of stem X 100 showing fibres (F) destroyed by black spores at R. T—Black spores X 600, two layers deep.

THE USE OF FORAGE CROPS TO LESSEN GRAIN DISEASES

Forage crops in rotation with grains offer the great advantage of helping to free the soil from fungi attacking cereals. None of the diseases of grains will attack legumes such as alfalfa, sweet clover, red clover, etc. Legumes also enrich and improve the soil. These forage crops have no diseases that are serious in Manitoba. It should be said, however, that mouldy sweet clover hay is likely to be poisonous to stock.

FUNGI AND PLANT DISEASES IN GENERAL

We have mentioned a number of fungi which cause injury to cereals. Few people realize what a vast world is that of the fungi. There are about eleven hundred flowering plants native to Manitoba, but we have found and placed in the herbarium specimens of 1600 species of fungi, and we have not yet found half of them. About 600 of these fungi are parasitic on about 400 species of green plants. These parasitic fungi include about 120 rusts, 40 smuts, and 400 species causing mildews, leaf spots, blights, etc.

This is still a comparatively new agricultural area, and plant diseases from older settled areas are bound to reach our crops in the future as they have in the past. He who grows plants should keep ever on the alert to keep down the losses which plant diseases may cause, for something can be done to lessen the loss from each plant disease, and many of them may be prevented entirely.

To those interested in nature the fungi provide an interesting and profitable study. For example, there may be found in Manitoba about 400 kinds of mushrooms and toadstools, and many other types of conspicuous fungi. Many of these are edible, and all are of interest.

Summary of Methods of Lessening Grain Diseases

Smuts can be prevented, as explained in detail in this bulletin. Seed treatment will prevent all our grain smuts except loose smuts of wheat and barley and corn smut. Clean seed or seed plots can be used to avoid the loose smuts.

Rust is still a serious problem, but progress is being made.

Crop rotation, the use of good seed, and other good farming methods will lessen the severity of many cereal diseases. It is important that the grain grower take observantly and carefully into consideration the diseases of his crops, and consider the means he may use to prevent them.

Problems for Students

1. Do you know of any cultivated barberries or buckthorn?

2. Is it possible to find a barberry growing wild in Manitoba?

3. Report rye smut if found.

4. Look for smut on heads of wild barley or green foxtail. Will these smuts injure grains?

5. What rusts or diseases can you detect in your gardens or flower beds?

6. Do you find evidences of disease on trees or other wild plants?

7. Make a school collection of mushrooms and toadstools. Every school should have a copy of "Mushrooms and Toadstools." Price $1.00, Department of Botany, Central Experimental Farm, Ottawa.

8. Looking for plant diseases and fungi will train your powers of observation. Send in to Biology Department, Manitoba Agricultural College, specimens you cannot identify.

Publications of Manitoba Department of Agriculture and Immigration Available for Distribution at time of Publication of this Bulletin

EXTENSION BULLETIN

No. 13—Common Diseases and Disorders of the Foal.
No. 20—Cheese Making on the Farm.
No. 34—Protection from Lightning.
No. 37—Farm Butter-making.
No. 38—Practical Cookery.
No. 42—The Cream Separator on the Farm.
No. 46—Lessons in Millinery.
No. 49—Hand Selection and Harvesting of the Seed Plot.
No. 52—Birds in Relation to Agriculture.
No. 54—Milk and Cream Testing on the Farm.
No. 60—Fattening, Killing, Dressing and Marketing Chickens.
No. 64—Laundering and Dyeing.
No. 65—The Beef Ring.
No. 66—Manitoba Potato Diseases and Their Control.
No. 67—Alfalfa and Sweet Clover Growing in Manitoba.
No. 73—Weeds of Manitoba.
No. 76—The Trench Silo.
No. 77—Hatching, Brooding, Feeding and Rearing Chicks.
No. 78—Beekeeping.
No. 79—Making Silage in Manitoba.
No. 80—Co-operative Marketing in Manitoba.
No. 81—Turkey Raising in Manitoba.
No. 82—Canning, Pickling and Preserving.
No. 83—Cleaning Seed.
No. 84—Breeding and Feeding the Market Hog.
No. 85—Dairy Cattle.
No. 86—Baby Beef Production in Manitoba.
No. 87—Dressmaking.
No. 88—Rusts and Smuts of Grains.

CIRCULARS

No. 66—The Gold Mine in the Backyard (Vegetable Growing).
No. 68—Weed Control in Manitoba.
No. 69—Couch Grass Eradication.
No. 71—Beautifying Home Surroundings (Decorative Gardening).
No. 72—Dealing with the Weeds Problem in Manitoba (How to Administer the Noxious Weeds Act).
No. 74—Garden Insects and Their Control.
No. 75—Manitoba Rations for Growing Bacon Pigs.
No. 79—Home-Made Brooders.
No. 81—Books on Decorative Gardening.
No. 83—Have You Dehorned Your Market Cattle?
No. 84—Good Seed Pays.
No. 86—Muskrat Farming in Manitoba.
No. 87—The Root Crop in Manitoba.
No. 90—A Simple Lesson on the Sow Thistle.

MISCELLANEOUS

Noxious Weeds Act (Manitoba).
Manitoba Annual Crop Report.

PLANT DISEASES NEW TO MANITOBA.*

G. R. Bisby and I. L. Conners

[Received for publication January 9, 1928.]

Manitoba is a comparatively new agricultural area, especially as regards crop plants other than the cereals. There are no other crop areas to the north or east. Manitoba marks a part of the northern boundary of cultivated plants. We have made an especial effort to detect plant diseases soon after they arrived here, and to determine how effectively the fungi causing these diseases persisted in this climate. The records given here cover a few of the more important or interesting cases, and include some diseases that may give increasing trouble; in most cases the evidence indicates that these diseases had not occurred previously in Manitoba.

Late blight of potatoes *(Phytophihora infestans)* has been reported vaguely from Western Canada before, but we had never seen a specimen from Manitoba until the autumn of 1927. It was found at Portage la Prairie, Otterburne and Miami, the fungus being especially well developed on the Otterburne material. It has probably been brought into Manitoba many times in the past on potatoes, and perhaps a trace of the fungus may perpetuate itself here year after year. It is possible that during a series of successive damp seasons it might accumulate to such an extent as to render spraying necessary. It will be watched for with especial interest in 1928. The similar climate along the Red River in Minnesota and North Dakota has not been conducive to the development of the late blight, and it is probable that the dry atmosphere will prevent any serious outbreak in the Prairie Provinces. However, we have already found that the use of Bordeaux mixture on potatoes pays in Manitoba even in the absence of late blight, with an average increase of about ten bushels per acre per spraying. Potato growers may, therefore, protect themselves here without cost.

Downy mildew of grape *(Plasmopara viticola)* has not been recorded heretofore from Manitoba. It made its first appearance in the orchard at the Agricultural College in June 1927, and increased to such an extent as to cause considerable injury. It was also prevalent at Morden this year, and we had not seen it there before. We feel that it is threatening enough to render advisable the spraying of our grapes next spring. It may happen that in a drier season this disease, like the similar late blight of potato, will be held in check. We assume that the fungus reached us as spores carried in the air. It occurs commonly in parts of Minnesota.

The powdery mildew of clover *(Erysiphe Polygoni)* has attracted considerable attention during the past six seasons. In 1921 the disease suddenly appeared abundantly in the eastern States. In 1922 it spread over the central States, and reached Manitoba. In 1923 it was serious here. Resistant plants are noticeable in infected clover fields, and some of these were selected out for use in case the disease continued to be serious. The mildew was not found at Norway House, 300 miles north of Winnipeg in

*Part of a report given at the meeting of the Canadian Section of the American Phytopathological Society, Winnipeg, December 20-21, 1927.

and early maturity, while further south and east a later maturing type is sought, the object being to provide summer pasturage at a time when bluegrass is least productive.

3. There is a wide range of variability to be found in sweet clover with respect to most plant characters. Owing to the phenomenal success of sweet clover as a cultivated crop, variability within different species of *Melilotus* is receiving much more study than has previously been the case. In the early stages of sweet clover breeding, it appears reasonable to assume that greater progress may be made in securing suitable varieties by working with a wide range of types than by extensive selection within the limits of common white or yellow flowered sweet clover from a single source.

4. Some exceptional types of sweet clover are described as to origin and characteristics. These were obtained as segregates in the progenies of certain aberrant sweet clover plants. Natural crossing and mutation are suggested as possible explanations of their origin. The plants are biennial in habit of growth and have the typical flower, pod and seed of white sweet clover. They differ from typical sweet clover chiefly in that they possess more numerous shorter leafy stems which develop from multiple buds at the crown. There are several types, some of which show considerable promise for cultivation. Early and late maturing strains with numerous fine stems have been obtained by inbreeding and selection.

5. *Melilotus albus* is highly self-fertile and sets seed freely without the aid of insects. Cross-pollination, however, occurs frequently enough to necessitate selection within self-fertilized lines as a standard breeding procedure. *Melilotus officinalis* sets very little seed when insects are excluded.

Self-pollination in *Melilotus albus* may easily be effected by caging the plants or bagging the racemes.

UNIVERSITY OF SASKATCHEWAN,
SASKATOON, SASK.

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1923. During 1924 and subsequent years the fungus has been present in southern Manitoba, but not especially serious.

The rust of red clover *(Uromyces fallens)* was also first found in 1922, and has persisted since. It is not a serious disease.

Onion smut *(Urocystis Cepulae)* was first found near Winnipeg by Professor W. P. Fraser in 1922. A little of it was collected in 1924, and more in 1925. During the past two years it has not been seen or reported. This smut continues to be rare here, despite the fact that onions are often planted successively on the same land. Onion smut is considered to be a disease of more northern regions, but nevertheless it appears not to thrive in Manitoba.

The powdery mildew of currants *(Sphaerotheca mors-uvae)* was first sent in from Cordova, Man., on August 21, 1924. It was collected on black currant bushes. There was only a slight infection, and no perithecia were present. In 1925, however, it was collected at Hazelridge on June 22 with perithecia present, at Brandon on July 3 and later at Valley River in the north and at Victoria Beach on the east side of Lake Winnipeg. All of these collections were on currants with the glandular leaves characteristic of *Ribes nigrum*. It has not been seen on either wild or cultivated gooseberries here. Apparently the fungus came into Manitoba about 1924; It has since been injurious to black currants each year. The mildew on gooseberry is evidently another physiologic form, and although it is indigenous to North America, appears not to occur in Manitoba.

The downy mildew of alfalfa (*Peronospora trifoliorum*) was found at Brandon in 1921 and at Winnipeg in 1923, and subsequently. It causes slight injury in local areas in alfalfa fields. It may have been present longer than our records show.

The leaf spot of alfalfa caused by *Pleosphaerulina briosiana* was found at Brandon in 1923. While it is of no economic importance, it is of interest to record the occurrence of this parasite, which is ordinarily considered to be limited to areas much farther south.

The anthracnose of peas *(Colletotrichum Pisi)* is another case of a disease scarcely to be expected in Manitoba. Chupp in his Manual of Vegetable Garden Diseases records it only from Ecuador, Japan, and Wisconsin. It caused some injury to garden peas at Brandon in 1923.

The brown rot of plums *(Sclerotinia)* is found in damp years such as 1922 and 1927. It seems to manage to persist, but does not find the climate congenial. It has probably been here for a number of years.

The ear or cob rot of corn caused by *Basisporum gallarum* is not uncommon, and has probably been present since corn has been grown in the province. It is noteworthy, however, that we have not yet been able to find *Diplodia Zeae* on corn in Manitoba.

The fungus *Sclerotinia sclerotiorum* is common in Manitoba. It has been found causing injury to sunflowers, red clover, alfalfa, carrots, parsnips, lettuce, dahlias, cucumbers, cabbage and on wild Canada thistle, nettle, sow thistle, and *Iva xanthifolia*. The sclerotia of course easily withstand our winters.

The downy mildew of spinach *(Peronospora effusa)* was first noted in 1926. It has, however, been found on wild lamb's quarters since 1920. This would seem to indicate that we have a native form on the weed, but that the form on spinach may be a distinct form and perhaps a new arrival.

A similar case is that of the downy mildew of cultivated sunflower (*Plasmopara Halstedii*) which has been found only in 1925, at Winnipeg. The mildew that passes under the same name may, however, be found each year on wild Compositae.

The leaf rust of barley *(Puccinia anomala)* was not very definitely found until 1927. In 1922 a few pustules bearing only red spores were found at Winnipeg, but we could not be certain that this might not have been some other leaf rust. In 1927 leaf rust was well developed on barley in several areas in Manitoba.

Snapdragon rust *(Puccinia Antirrhini)* was first collected at Winnipeg early in 1920, but a market gardener reported that he had seen it in 1919. This rust is native in the mountains of California, and was not found east of the great plains until 1913. It has been injurious here since 1920.

Corn rust *(Puccinia Sorghi)* was not found in Manitoba fields until 1922. It has been common each year since.

The Grand Rapids disease of Tomatoes, caused by *Aplanobacter michiganense*, was first collected at Brandon in 1927 and the typical non-motile bacteria producing yellow colonies were isolated This disease has been reported from the eastern and southern states, and also from British Columbia.

These examples indicate clearly that many diseases found elsewhere in North America, or in other parts of the world, may be expected sooner or later to reach Manitoba, and once they have arrived, the fungi are usually able to withstand our winters. The dry atmospheric conditions of Western Canada serve, however, as an effective check against certain diseases.

When agricultural crops are first grown in a new area, they may arrive without the diseases prevalent in localities where they have long been grown. This is illustrated by the case of tobacco, which has recently been cultivated to some extent at Morden. Aside from mosaic, we have been unable to find any disease on this crop; the leaves are beautifully free from spots caused by fungi. Yet doubtless the fungi will gradually arrive, as they did long since on cereals, and more recently on fruit, vegetable, and forage crops. As Manitoba grows older, more and more attention must inevitably be paid to the increasing number and prevalence of plant diseases. To be forewarned is to be forearmed, and growers who take intelligently into consideration the prevention of plant diseases will be amply repaid.

MANITOBA AGRICULTURAL COLLEGE,
WINNIPEG, MAN.

Hawaii

PERHAPS the best way to start is to include a few entries from my diary:

"Thu. Apr. 21, 1927. Left Winnipeg at 4:45 P.M. Soon met a Major Wilcox of South Africa, who had just come from 3 months at Honolulu. He was very fond of Hawaii, and told me much about it.

"Sat. Apr. 30: Salt Lake City was welcome after the Wyoming desert. Visited the Tabernacle and heard the organ. Discovered that the second largest Mormon temple is in Hawaii.

"Wed. May 4: Sailed from Vancouver at 12:15 P.M.

"Tue. May 10: The weather is considerably warmer. The Pacific is calm, as it always seems to be. Flying fish are more abundant. Spent the day reading, visiting, playing deck games, and looking at the ocean.

Wed. May 11: Arose at 6:00, and found the island of Oahu standing over the starboard rail, bathed in hazy sunrise. Honolulu in the distance over the bow. We landed to the strains of "Aloha," and everyone was disembarking to put leis of flowers over his head. It seemed like a paradise on shore....."

But I must not give you all of my diary. You will agree that few cities of a hundred thousand population have more widespread fame than Honolulu. I have never found a place which so amply fulfilled one's anticipations; about which there was such unanimity of opinion as regards its excellence. Everyone has sung of Honolulu, of Waikiki Beach, and knows the haunting strains of "Aloha." And there are ukeleles and Hawaiian guitars even in Hawaii—and even the natives play them: or perhaps I had better say that no one but a native can play them!

Hawaii presents the tropics at their kindest and best. Two thousand miles from any mainland, it has kept free from many pests. The endless Pacific keeps the climate moderate. Each advantage of civilization is at hand if you must have it. And there are cocoanut palms that drop a meal at one's feet and bougainvillea actually growing out of doors in a riot of color.

For a serious minded Professor, there are the Bishop Museum, the University of Hawaii, the Hawaiian Sugar Planter's Association Research Department, the Aquarium full of unreal Hawaiian fish, the sugar cane and pine apple canneries; the highly developed agriculture and the fascinating vegetation of the tropics. Hawaii is one of the few places on earth where tree ferns grow wild. For one not too professional there is the warm sea in which to bathe, the palms beneath which to rest.

My stay on the island of Oahu was short, but the memory of the place makes each winter day more pleasant. Like everyone else who has seen Honolulu, I plan to go back.

I may as well close with the final entry in my diary of Hawaii:

"This book rests upon the rail of the Aorangi as we sail past old Wakiki Beach, with the Royal Hawaiian Hotel glowing in the setting sun against a cloud-capped background of gray volcanic mountains. It is with a feeling of sadness that I see the palms of the sandy beach fading away into the distance.....Diamond Head still stands clear-cut before us, but the rest of Oahu has disappeared into the haze; Aloha!"

G. R. Bisby

Address by Miss Esther Thompson to M.A.C. Alumni Association

IT IS my privilege tonight to speak on behalf of the women who have attended the Agricultural College and bring thanks to the College for the gifts it gave us, to those who determined what those gifts should be.

On an occasion such as this, it is pleasant to remember that the College had not long been open when the women were thought of, when a place was provided for them. It is also gratifying to recall how quickly the course developed after it was established, from the short course offered in 1910 to the five year course offered in 1914. The establishment of a course for women so early in the history of the Agricultural College and the rapid development of it reflect the vision and the courage of the founders —those we have met to honor to-night.

Being a member of the first group of women to obtain the degree of Bachelor of Home Economics, I remember well how troubled we were when we came to the end of the second year, how insistently we pleaded that we be permitted to come again, and how we waited for the extension of the course. The going of the snow, the return of the birds, the wine of the spring air and the rushing towards us of the last day when we must leave made us more insistent and impatient. You can therefore well understand our joy when we were assured before leaving for home that the President and the Advisory Board had decided to add three more years to our course. Our cup was then full to the brim and running over. I wonder if second year girls, since that time, love their course and the College as we loved both, and desire as much to come back!

The course was extended and we came back, and then followed three unforgetable years for the professors and for us. The professors' lot was not an easy one. The course which we had been taking, excellent as it was, had not quite fitted us for the advanced work, and so it happened that a professor was frequently required to build a bridge between his or her subject and the class, to carry the student over the bridge to the subject or the subject to the class. I have a feeling that even this method failed sometimes. Little wonder then that the professors were tried, and I do not know what our fate would have been had we not followed them about like Mary's little lamb, blissfully unaware of our limitations.

To us the three years were a great adventure, although we did not always think so at the time. We had many unique experiences. We were seniors for four years. The pretty girls of our class were caught up in the whirl of social functions at the end of each year. They were invited to the professors' parties and to the graduates' dinner, which was in those days one of the functions of the year. Not being among the pretty girls, I remember being invited to only one graduates' dinner, and the reason was that they wanted someone to reply to the Toast to the Ladies. This, by the way, brings me to a grievance which I want to lay at the feet of the Agricultural College and the men students. Indeed, I mean to leave it there as a little token of our resentment. Some of the girls who came to

Publications in Manitoba, 1921-23

Guy Richard Bisby, B.S., Ph.D. (Minnesota), *Professor of Plant Pathology* (1920-).

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DEPARTMENT OF ENTOMOLOGY

Alvin Valentine Mitchener, B.A. (McMaster), B.S.A. (O.A.C. Toronto), *Assistant Professor of Entomology* (1918-).

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2. Field Crop Insects in Manitoba. *Agricultural Gazette of Canada*, Vol. X, No. 4, July-August, 1923, pp. 333-336.

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2. The Western Wheat-stem Saw-fly (*Cephus Cinctus Nort.*). *Department of Agriculture Circular*, No. 57, August, 1920, pp. 1-4.
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DEPARTMENT OF ANIMAL HUSBANDRY

Gordon W. Wood, B.S.A. (McGill), *Professor of Animal Husbandry* (1917-).

BULLETIN

1. Rearing Dairy Calves. *Manitoba Farmers' Library*, 50, 1920.

Address by Miss Esther Thompson to M.A.C. Alumni Association

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